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100 PROBLEMS IN ENVIRONMENTAL HEALTH

W. L. Faith, et al

California Institute of Technology
Pasadena, California

1961

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AIR POLLUTION
FOOD SCIENCE and TECHNOLOGY
OCCUPATIONAL HEALTH

100 PROBLEMS
IN
ENVIRONMENTAL HEALTH

Edited by
Jack E. McKee, Sc.D., W. L. Faith, Ph.D.,
H. Heukelekian, Ph.D.,
Thomas F. Mancuso, M.D., M.P.H.,
Emil M. Mrak, Ph.D., Clair N. Sawyer, Ph.D.

WATER SUPPLY
and WATER POLLUTION
SOLID WASTE DISPOSAL
and MISCELLANEOUS

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100 PROBLEMS
IN ENVIRONMENTAL HEALTH

A Collection of Promising
Research Problems

EDITED BY
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ON BEHALF OF THE
EIGHTY-THREE SCIENTISTS WHO HAVE JOINED
IN SPONSORING THIS VOLUME BY CONTRIBUTING
TO ITS CONTENTS, AND OF ALL OTHERS INTERESTED
IN THE PROGRESS OF RESEARCH IN THIS FIELD
OF SCIENTIFIC ENDEAVOR

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1961

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This work was made possible by grant No. RG-7263 (later
redesignated EF-243) from the Public Health
Service, Department of Health, Education, and Welfare
Bethesda, Md.

PREFACE

Environmental health, or more specifically the healthfulness of the environment, relates to the impact of man's activities on his surroundings and the concomitant effects of these environmental changes on man. It is a broad field, embracing a wide spectrum of scientific disciplines, many of which must be integrated and coordinated for the solution of specific problems.

The rapid growth of population in metropolitan areas, the intensified industrialization of our complex society, and the acceleration of technological development have focused attention on the present and potential dangers arising from environmental factors such as air pollution, the contamination of water supplies, sewage and industrial wastes, radioactive substances, insecticides and herbicides, contamination of food by chemical and biological agents, occupational hazards, solid waste disposal, deterioration of recreational waters, and many others. To health officers, engineers, and scientists confronted with these dangers, the number, variety, and complexity of the problems are appalling. Furthermore, the future threatens to bring even greater hazards.

Recognizing that the scientific personnel presently engaged in research to solve these problems are woefully inadequate in numbers (and perhaps even in certain special abilities) to handle the present task, let alone the future threats, several of us engaged in research and practice in the field of environmental health hit upon the idea of spotlighting the problems with the hope that such publicity might inspire new workers in a variety of disciplines to enter the field. Specifically, therefore, it is the intent of this booklet to aid in recruiting scientists from various disciplines to study problems in environmental health, and to suggest needed research to those individuals who are not aware of the scope, magnitude, and variety of unsolved problems.

Before turning to specific areas of interest in this booklet, the reader should peruse the section entitled "Introduction" and note especially the scope and limitations of the material, its organization and indexing, and precautions relative to its use.

This publication represents the suggestions and cooperative efforts of over eighty scientists, engineers, and medical doctors in educational institutions, governmental agencies, professional practice, technical associations, and commercial enterprises. The major credit for this booklet goes to these contributors, who are listed on the following pages. Their cooperation in submitting problems is gratefully acknowledged. Most of the work of soliciting the problems and editing them to eliminate duplication or overlapping, and indexing them by disciplines was performed by the board of editors, ably assisted by their respective secretaries. Incidental expenses of solicitation, typing, etc., and the cost of publication were met by a grant (RG-7263) from the National Institutes of Health, which was deeply appreciated. Finally, we are indebted to Dr. Errett C. Albritton who inspired this work and assisted in its development.

J. E. McKee

California Institute of Technology
Pasadena, California

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INTRODUCTION

As pointed out in the Preface, it is the goal of this booklet to inspire scientists in a wide spectrum of disciplines to tackle the multitude of unsolved problems related to environmental health. Over one hundred such problems are described briefly in this publication, but the list is far from complete, as any worker in this field will attest. Indeed, anyone acquainted with one or more phases of the vast environmental health picture can quickly think of several corollary or completely separate problems. With little additional effort, this list could have been expanded to "200 Problems".

The reader may recognize, furthermore, that many of the problems described in this booklet are not new. In fact, some of them have been studied for a decade or longer and others are currently under investigation. Nevertheless, they still represent unresolved problems that deserve continuing and intensified investigation.

The booklet has been divided into several major categories (air, food, occupational health, water, etc.) for the convenience of the reader. It should be recognized, however, that some of the problems overlap these arbitrary divisions. Furthermore, a research worker in a specific scientific discipline such as bacteriology or physical chemistry may be interested in all of the categories. For this reason, the problems have been indexed with respect to disciplines as well as by subject areas.

In the presentation of each problem, an attempt has been made to describe the background and to outline the present state of knowledge relative to the subject. Some possible lines of attack are suggested but there is no intent to limit the approach or to prescribe specific methodology. Finally, some important references are given in case the reader wishes to delve into the problem more deeply.

The contributors of specific problems have not been identified, for several reasons. First, some of them asked to remain anonymous;

second, the editors have frequently combined the suggestions of two or more contributors into one problem; and third, any proprietary interest in a specific problem is avoided. Nevertheless, the bulk of this booklet represents the work of the contributors as listed hereinbefore, and in their generosity in sharing their knowledge of these problems is deeply appreciated.

The editors of this booklet have all been members, at one time or another, of panels established by various agencies of the federal government to review research grant applications. These associations, and the fact that the publication of this booklet has been financed by a grant from the National Institutes of Health, give no assurance that a project application patterned after one of the "100 problems" will be given high priority or *carte blanche* approval. A grant application addressed to any agency is always subject to the agency's customary procedures of review and evaluation.

SECTION 1. AIR POLLUTION

Problem No.	**Title**
101	The Nature of the Photochemical Eye Irritant in Smog.
102	Economic Removal of Sulfur Dioxide From Power Plant Stack Gases.
103	The Nature of Individual Particles in Smogs and Other Hazy Atmospheres.
104	The Continuous Measurement of Odors.
105	Effects of Weather Conditions in the Evaluation of Community Air Pollution.
106	The Nature of the Primary Process and the Primary Quantum Yields of the Photolysis of Nitrogen Dioxide in Polluted Atmosphere.
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125	Mechanisms For the Removal of Sulfur Dioxide From the Atmosphere.

101. The Nature of the Photochemical Eye Irritant in Smog

The Problem: Eye irritation is a major nuisance of the smog that plagues Los Angeles and other West Coast communities. The actual eye irritant has never been identified. The only way in which it has been reproduced in the laboratory, at pollutant concentrations similar to those found in the atmosphere, is by irradiation of certain hydrocarbons and nitrogen dioxide. Identification of the irritant would help clarify the mechanism by which it is formed and the development of adequate controls.

Previous Work: Early work by Haagen-Smit at Caltech indicated that irradiated mixtures of hydrocarbons and nitrogen dioxide produced an eye irritant. This finding has been corroborated further by Morriss and Bolze at Midwest Research Institute, by various workers at the Los Angeles County Air Pollution Control District and at Stanford Research Institute, and more recently by Darley and his colleagues at the University of California, Riverside.

Schuck, Ford, and Doyle at Stanford Research Institute have recently shown that olefins are the most prolific producers of eye irritation when irradiated in the presence of nitric oxide or nitrogen dioxide. Diolefins are by far the most effective members of the class. There is some evidence that the irritant may be a mixture of formaldehyde, acrolein and a nitrogen compound (possibly peroxyacetyl nitrate), but this is not certain. Others have postulated that a free-radical mechanism is involved. There are also those who believe that the irritant is transported to the eyeball adsorbed on aerosol particles.

Rogers and Schuck estimated the half life of the eye irritant to be about 24 hours under static conditions.

Potential Physical Chemical Research: Several lines of attack will be required to solve the problem. Physical chemical research will involve the physical and chemical identification of the products of the photochemical oxidation of gaseous organic compounds at concentrations not exceeding 3 ppm. Spectrographic methods may be adequate for the determination of the more stable intermediate products, but determination of some of the transient intermediates with very short half-lives will require considerable ingenuity. Identification and quantitation may be accomplished by extending the sensitivity of spectrographic methods into the parts-per-billion range or by developing entirely different methods for capturing and measuring highly reactive molecules.

Physiological Research: One of the greatest needs of the eye-irritation field is the development of objective methods for evaluating the presence and degree of eye irritation. The only extensive and well-controlled study of eye irritation induced by photochemical reactions has been carried out at Stanford Research Institute. Various degrees of eye irritation, labeled severe, moderate, and light, have been reproduced satisfactorily within ± 10 per cent by the use of panels of 10 individuals, various psychological tricks to diminish bias, and frequent calibration with previously studied systems. The method is cumbersome and expensive. It is open to criticism because it involves a subjective response.

Perhaps some physiological or biochemical tests of tissue cultures or of experimental animals could be devised, which would obviate the need for human panels. Few pertinent suggestions have been made, so the field is wide open.

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102. Economic Removal of Sulfur Dioxide from Power Plant Stack Gases.

The Problem: Sulfur dioxide is recognized widely as an undesirable air contaminant. The greatest quantity reaching the atmosphere is in the combustion effluents of sulfur-bearing fuels. Generally, stack concentrations are sufficiently low that conventional methods of removal are not economically feasible.

The State of the Art: British investigators have been particularly active in trying to develop methods for removal of sulfur dioxide from flue gases because of the widespread use of high-sulfur coal in Great Britain. Three power plants in England use a gas-scrubbing process in which the sulfur dioxide is removed by reaction with alkaline solutions, but attempts to use this process elsewhere have always failed because of unfavorable economic conditions, creation of a serious liquid-waste disposal problem, and poor atmospheric dispersion of the cooled gases.

A process developed by H.F. Johnstone of the University of Illinois oxidizes sulfur dioxide catalytically with manganese ions. The resulting sulfuric acid is then concentrated for sale. Again, economics have not been favorable. A process using ozone as the oxidant has met a similar fate. Various other processes, involving liquid absorption, adsorption on solids, reaction with solids, and reduction of the sulfur dioxide, have been studied extensively but have not been successful commercially.

Haagen-Smit attempted to oxidize SO_2 catalytically and then to react the SO_3 with fly ash in the stack effluent by hydration and neutralization, with subsequent removal of solid sulfates in an electrostatic precipitator. Again, economics interfered with adoption of the process.

A partially successful method for minimizing sulfur dioxide emissions has been treatment of the fuel before burning to reduce its sulfur content. For this purpose coal has been cleaned mechanically to reduce pyritic sulfur gasified either partially or completely, or carbonized at both low and high temperatures. In some cases partial economic success has been attained.

Removal of sulfur from fuel oil before burning has involved hydrogenation and various types of treatment. Satisfactory progress has been made in producing low-sulfur distillates, but the cheaper, more widely used, residual fuel oils appear to defy economic desulfurization.

Potential Lines of Attack: It is extremely difficult to point out a plan of research that has not already been explored several times. In fact, if one could devise a feasible method on paper, the problem would be more than half solved. The chemistry of sulfur and its compounds is well developed, and it is doubtful that new types of reactions can be uncovered. The break-through will undoubtedly have to come from ingenious engineering developments.

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103. The Nature of Individual Particles in Smogs and Other Hazy Atmospheres

The Problem: The most common attribute of smog, and that probably affecting most people, is reduced visibility occasioned by small particles in the air. More information on the chemical and physical nature of these particles, both in "natural haze" and smoggy atmospheres, is needed to relate visibility effects to industrial and domestic emissions and to guide medical research on the role of particulate matter in respiratory diseases.

Previous Work: A tremendous effort has gone into determining the chemical nature of particulate matter in the air near the surface of the earth, both in smoggy city air and in comparatively unpolluted atmospheres. Most of this work has involved the collection of particulate material in bulk on high-volume filters, followed by a general analysis of the collected material. Some information is available on the composition of individual particles of various sizes.

Work at Stanford Research Institute showed that many of the particles in Los Angeles air during smog sieges were essentially contaminated water droplets, even when the relative humidity was as low as 50 per cent. Unfortunately, most studies of photochemical smog have ignored the water fraction of the particulate material.

Even less is known about the constituents of the natural hazes that are often found inland, even in relatively uninhabited mountainous and desert regions. Dr. Frits W. Went has suggested that these hazes may result from the photochemical oxidation of unsaturated hydrocarbons given off by plant life.

Considerable information is available concerning the nature of particulate matter from industrial and domestic sources, and more work on this subject is under way. This knowledge should be a useful guide in determining the nature of the atmospheric particles in a given geographic location.

Lines of Attack: Both smoggy and hazy atmospheres should be sampled in many different locations--industrial, desert, mountainous, tropical--wherever a man-made or natural haze abounds. At least two techniques are presently available; probably both should be tried. One is the type developed by Lodge, Seely, and others; the other is the chemical micrurgic technique used at Stanford Research Institute. Research of this nature can be carried out at various levels of effort, depending on personnel and equipment available.

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104. The Continuous Measurement of Odors

The Problem: Odor is one of the first manifestations of air pollution. It is frequently the factor that arouses emotional reactions in people to the greatest degree. Yet, we do not have an instrument that can indicate or record atmospheric changes that can be reliably correlated with odor changes. In contrast, light and noise can be effectively measured by instruments. The methods now used for odor measurement involve personal judgments by a number of people; results obtained are expensive and lack the desired precision.

Previous Work: Since it is generally assumed that odor is related to the presence of extraneous gases and vapors in air, efforts have been made to determine the over-all atmospheric content of such materials. Since material concentrations are very low, the method must either be very sensitive or be able to concentrate odorous vapors to measurable quantities. Methods of concentration, however, are time-consuming and cannot be considered to give information on odor at any specific time. One of the sensitive detection techniques is that of change of potential energy at the surface of a solid by an organic vapor, as described by J.R. Eaton of Purdue University. There is, however, no satisfactory correlation between organic matter *per se* and odor. Odor differences among different compounds are, in fact, tremendous. Another technique that is highly sensitive and may be considered is long-path infrared spectrometry. Although infrared spectral records give information on specific molecular functional groups, even this information cannot yet be satisfactorily correlated with odor.

Possible Lines of Approach: It is first important to know the material determinants of odor. Specific functional groups, molecular size and shape, solubility in water and fat, and interactions among different kinds of molecules have all been examined and are no doubt all important, but no synthesis of this information is available. It may be possible to program such data into computers so as to develop quantitative relationships between instrumentally measured attributes and perceived odor qualities. This approach may initiate leads to the design of measurement systems.

As a conceivable alternative, it may be possible to investigate the enzyme system involved in olfactory perception. If this were understood and could be duplicated by an enzyme preparation in vitro, it might be possible to use biochemical preparations from animal sources as odor indicators.

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105. Effects of Weather Conditions in the Evaluation of Community Air Pollution.

The Problem: The evaluation of the significance of a community's air-pollution problem, or of the success of an air-pollution-control program, involves comparisons of observed concentrations of contaminants at different locations and at different times. Direct comparisons are rendered very difficult by the normal diversity of weather conditions, which in any noncontinuous sampling program limit investigators to reporting an "observed range" of concentrations. A method of estimating the extent of dilution of urban atmosphere relative to some standard weather conditions would greatly enhance the utility of contaminant surveys of short duration and limited scope.

Background: Recently the Department of Public Health of the State of California promulgated a set of standards for quality of urban atmospheres. This regulation takes the form of a list of substances common in polluted atmospheres, together with estimated concentrations required for the causation of specific air-pollution effects. (For example, a community may be considered to have a serious air-pollution problem, resulting in probable physiological effects on residents, if the concentration of sulfur dioxide should remain above 5 parts per million for an hour or more.)

Unfortunately, the determination of whether the standard levels are occasionally exceeded in a community requires an extended program of air monitoring, which may be too expensive for the means of the community. However, much information is available from metropolitant areas that have well-recognized problems, such as Los Angeles, where dozens of air-monitoring devices have been operated continuously for several years. Existing data can be utilized to examine the relationships of smog manifestations to contaminant concentrations and weather conditions in considerable detail. In addition, atmospheric factors not previously recorded could be profitably studied with much less effort at such locations than in places where no backlog of information has been accumulated.

Suggested Approach: If an urban atmosphere contained some gaseous component emitted in the community at a constant rate but not found in fresh air arriving from elsewhere, then clearly the concentration of that component could be taken as an inverse indicator of the rate of dilution of urban air by fresh air; that is, of the "ventilation rate" for the living space of the community. This ventilation rate would be necessarily a function of the meteorological conditions (wind speed and direction, inversion heights, etc.). In fact, for comparing conditions with respect to air utilization, it would be the single most directly relevant function of those conditions. Although there is no gaseous product emitted at a strictly constant rate by any community, it appears possible to use the same principle to estimate ventilation rates, provided that a component can be found whose emission rate varies relatively slowly and within reasonable limits, or with ascertainable cycles.

Among the substances that might be considered as possible indicators of micrometeorological ventilation rates are total hydrocarbons or carbon monoxide, mainly from auto exhausts; sulfur dioxide, from coal or fuel oil combustion; and carbon dioxide, from all combustion. A highly controllable means would be the deliberate introduction into the atmosphere of a nontoxic gaseous tracer substance.

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106. The Nature of the Primary Process and the Primary Quantum Yields of the Photolysis of Nitrogen Dioxide in Polluted Atmospheres

The Problem: Nitrogen dioxide is by far the most important absorber of solar radiation in polluted urban air and the reactions initiated by this absorption are of basic importance in the process of photochemical smog formation. It is known that the absorption of radiation at 3660 Å and shorter wavelengths dissociates nitrogen dioxide into nitric oxide and an oxygen atom , and it is known that no reactions are produced by absorption of wavelengths above about 4350 Å Between these wavelengths photochemical reactions are produced, but the nature of the primary process is uncertain. Thus at 4050 Å the experiments of Hall with oxygen isotopes indicate that no photodissociation occurs, yet nitrogen dixoide is decomposed [2,3] and also reacts with olefins on absorption of this wavelength.

Since the rate of absorption of solar radiation by nitrogen dioxide reaches its maximum at wavelengths just above 4000 Å, the problem of the nature of the primary process and the primary quantum yields in this region of uncertainty is of particular importance to an understanding of the mechanism of photochemical smog formation.

Possible Approaches: Only two primary photochemical processes appear to be possible with nitrogen dioxide--a dissociation into nitric oxide and oxygen atoms and the formation of excited molecules which undergo chemical reactions. The first approach suggested, therefore, is to determine the primary yield of the dissociation at several wavelengths between 3660 and 4350 Å.

This determination might be accomplished in several ways. For example, with small concentrations of nitrogen dioxide in the presence of a large concentration of oxygen only two secondary reactions are important--the reaction of oxygen atoms with molecular oxygen to form ozone and the reaction of nitric oxide with this ozone to regenerate nitrogen dioxide. Under these conditions a stationary concentration of ozone will be established, the square of which will be proportional to the rate of nitrogen dioxide dissociation. By measuring the rate of light absorption and the ozone concentration, the primary yield may be determined.

Another method of determining the primary dissociation yield would employ isotope exchange. On irradiating a mixture of NO_2 and O^{18}-enriched oxygen, the rate of appearance of O^{18} in the NO_2 should be proportional to the primary dissociation rate.

After the primary dissociation yields are determined the next step might be to turn to known reactions and to determine the contribution of activated molecule processes to those reactions. Thus, in the reaction of nitrogen dioxide with olefins this might be accomplished by adding an excess of some substance which removes oxygen atoms, such as nitric oxide or hydrogen, or, since the oxygen atoms and activated molecules will probably have different lifetimes, by using a flow system with introduction of the olefins at different distances down the flow tube. It might also be accomplished simply by measuring the difference between the rate of reaction with the olefin and the rate of dissociation.

Facilities: The primary requirement is a light source and a monochromator or other arrangement capable of delivering radiation of the required intensity at a number of wavelengths in the region 3660-4350 Å. Other facilities required will depend on the method of attack chosen; measurement of the stationary ozone concentration would require a long-path infrared spectometer or other instrument capable of measuring low ozone concentrations, whereas the isotope exchange approach would require access to a mass spectrometer. Experience in photochemistry and gas-phase reaction kinetics would be required.

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107. Acyl Nitrates in Photochemical Smog.

The Problem: Current evidence indicates that the compound X formed in urban atmospheres as part of photochemical smog consists of acyl nitrates . These substances are photolyzed by solar radiation, but the nature of the photolysis is unknown. Several dissociation processes, as well as internal rearrangements, are possible , and the problem is to determine which of these processes actually occur.

Possible Approaches: The standard methods for determination of the mechanisms of photochemical reactions should be applicable to this problem. The first task should consist of a determination of the over-all products of the photolysis and the variations in these products with varying experimental conditions. The next step might consist of an investigation of the rate laws involved in the formation of these products. Further steps should be based on the findings of these investigations.

Facilities: This problem is comparable in scope and importance to the investigations of the photochemistry of other classes of organic compounds, such as the aldehydes and alkyl nitrites, and will require comparable facilities and time for its solution.

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108. The Role of Sulfur Dioxide in the Formation of Atmospheric Aerosis.

The Problem: Sulfur dioxide is one of the most ubiquitous gas-phase pollutants of urban areas. It is also a component of the particulate matter formed in the atmosphere. It is subject to photolysis in sunlight. It leads to aerosol formation by at least two different processes: (1) through sulfur trioxide to sulfuric acid in the presence of water vapor and (2) through photochemical reactions to sulfur compounds in the presence of olefinic hydrocarbons and nitrogen oxides. Understanding of these processes requires answers to the following: What are the mechanisms by which sulfur dioxide in the gas phase goes over to sulfur compounds in the particulate phase? Are both condensation mechanisms and chemical reactions involved? Do some reactions proceed in the dark? If so, what are the kinetics for the reactions?

Previous Work: Blacet, Hall, and Johnstone and his colleagues have studied the photooxidation of sulfur dioxide. Mechanisms have been suggested, but they have not been unequivocally determined. Doyle and Renzetti have studied the photooxidation of sulfur dioxide alone in pure air and in the presence of hydrocarbons and nitrogen oxides.

Potential Physical Chemical Research: The lines of investigation that should be pursued in order to understand fully the role of SO_2 and its derivatives in polluted atmospheres are as follows: (1) Establish the mechanism of sulfur dioxide photolysis in sunlight at 1 ppm concentration, the kinetics of the reactions involved, and the nature of the products in pure air. (2) Establish the mechanism of the photolysis of sulfur dioxide and nitrogen dioxide at parts per million concentrations in pure air in sunlight. Determine the kinetics of the reactions involved and the nature of the products. (3) Establish the mechanism of the photolysis of sulfur dioxide in the presence of nitric oxide in sunlight. (4) Study the photolysis of sulfur dioxide in the presence of olefinic hydrocarbons alone and with nitrogen dioxide in air in sunlight. (5) Study the effect of other agents in polluted atmospheres as potential nuclei for aerosol formation in those situations given above, which are found to lead to significant solid or liquid particulate concentrations as regards reduction in visibility. Some of these agents are acids, such as phosphoric; alkalies such as Na_2CO_3; salts, such as NaCl KCl, sulfates, etc.; metallic oxides of Fe, V, Pb, etc.; and organics, such as oleic acid esters.

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109. A Study of the Nature of the so-called "Acid-Aerosol" Spotting of Leaves of Various Plants.

The Problem: From time to time, spotting of leaf surfaces of various plants, and even holes in the leaves have been noticed in some areas subjected to intense air pollution. Some investigators have thought the damage was caused by sulfuric acid aerosols, but little tangible evidence of this theory has been produced. An air-pollution regulation recently adopted in Los Angeles County had as one of its objectives the prevention of "sulfuric acid aerosol" damage to vegetation. Limited spotting of the leaves of table beets, myoporum, chrysanthemums, and other plants had been noticed in the Los Angeles area, and it was alleged this damage was caused by sulfuric acid aerosols.

Previous Work: Supposedly, spots and holes in certain leaves are caused by sulfuric acid aerosol droplets deposited directly in concentrated solution from an unsaturated atmosphere or collected as sulfur dioxide on moist leaf surfaces in saturated air, the sulfur dioxide being subsequently oxidized and the acid concentrated as the leaf surface dries. These postulates were advanced about 10 years ago in connection with aerosol work in Salt Lake City, but have never been established experimentally in the field. In fact, recent unpublished work by Noble of the Los Angeles County Air Pollution Control District has failed to show any sulfate associated with the spots.

In view of the importance that sulfuric acid aerosol is exhibiting in some air pollution situations, notably in London and, inferentially, in Los Angeles, it would be desirable to study this oxidation in the field and to determine if this spotting is ever due to acid and, if so, under which conditions. Thomas studied the process under laboratory conditions and reported that attempts to duplicate leaf spotting from sulfuric acid aerosols were unsuccessful.

In addition to field studies on sulfuric acid aerosols, it will probably be helpful to survey areas where this type of injury has been reported as well as areas where it would be expected to occur if sulfuric acid mist were the culprit. One could obtain clues as to whether sulfuric acid or some other pollutant is the causative agent, or whether disease is involved.

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110. Are Motor-fuel Additives Hazardous to Public Health?

The Problem: In 1923, when the addition of tetraethyl lead to motor fuel was first considered, it was felt that there was insufficient information concerning the possible effects of this addition on the public's health. In 1959, a second review of this problem was undertaken, with no essential change in the conclusion. At the present time, the amount of tetraethyl lead added to motor fuel is being increased slowly. Other substances are also being added, including tetramethyl lead, various manganese compounds, and organic phosphates. Concentrated amounts of each of these substances present problems of toxicity which have generally been handled skillfully by the industries that manufacture and distribute the additives or the fuel containing them. Although the information developed for the control of industrial hazards from additives is very useful, it is not directly applicable for evaluation of community hazards. On the other hand, no one has proved that the present levels of pollution from motor-fuel additives are damaging to the public's health.

There is a need to establish principles and limits to determine the toxicology of motor-fuel additives and their products, especially on the health of the public. Such guides should be promptly incorporated into practices concerning the addition of such substances to motor fuels.

Background: Several different approaches have been used in the past. For example, measurements of lead in urban atmospheres have been made over a number of years. The proportion of lead from motor-fuel additives and the proportion from other sources may vary from place to place. However, in areas with a good control program for industrial air pollution and a high population of motor vehicles, it is likely that most of the atmospheric lead does come from motor-fuel additives.

From what is known of the toxicology of lead, it is clear that the likelihood of acute toxicity in public exposures is very slight. The problem, then, is one of chronic toxicity. Industrial toxicologists have found that if lead is accumulated in the body from a given exposure at a rate exceeding that for non-exposed persons, there is some risk of toxicity. This general principle seems appropriate as a guide for the toxicology of community air pollution from exhausted lead.

Past studies have also shown the particle size distribution of lead from motor vehicle exhausts and have indicated that in certain particle ranges a very high proportion, in excess of 50 per cent of inhaled lead, may be deposited in the lungs. It is also known that less than 10 per cent of orally ingested lead is retained in the body.

Potential Lines of Attack: It is important to evaluate systematically the relationship between atmospheric lead and motor fuel use, possibly by more detailed chemical analysis of particulate lead, as well as more detailed analysis of the particle size of lead in the atmosphere. The latter approach would also permit better estimation of the amount likely to be retained.

In addition, it would be very reasonable to determine average lead values in the blood and in urine of persons with various types of daily exposures. For example, drivers who spend much time on the freeways could be compared with service-station attendants, policemen, firemen, and clerical workers. The same methods should be applied to persons who have an occupational lead exposure in industries in which lead is widely used. An additional approach would be to study the amount of lead in various organs of persons who have no known occupational exposure. The analysis should be done in a laboratory fully familiar with the study of small amounts of lead. Generally speaking, spectographic analysis has proved to be a most efficient technique.

Other Pertinent Considerations: These studies should not take more than four or five years. This is a very urgent problem and one that should be studied and resolved without delay. The work should be carried on in several localities, but it should be centralized by an agency, such as the U.S. Public Health Service, with laboratory and toxicologic facilities. The disciplines involved might include pathology, toxicology, clinical medicine, chemistry, and spectroscopy. Also important in this study would be engineers familiar with motor vehicle operations.

The principles outlined above would also apply to the study of other possible additives each of course being considered with respect to its own peculiar properties when added to the pollution in the atmosphere.

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III. Minor Obnoxious Products in Stack Gases.

The Problem: Sulfur dioxide, carbon monoxide and fly ash have been recognized as components of stack gases that occur in concentrations that depend upon the fuel used and the operating conditions. Other obnoxious products appearing in lesser quantities include oxides of nitrogen, hydrochloric acid, sodium hydroxide, and compounds of such elements as phosphorus and arsenic.

The State of the Art: Experience with eye irritants in the Los Angeles area have focused attention on oxides of nitrogen. Various investigators have measured the content of oxides of nitrogen in powerplant stack gases, but very few data have been reported. It appears that the concentration depends upon operating conditions, the concentration increasing with high flame temperatures and rapid cooling. Published data are needed, particularly for different types of large coal-fired furnaces.

Damage by alkaline deposits has resulted from incineration of chemical sludges containing a high content of sodium chloride. A separation of hydrochloric acid from alkali must have occurred. The alkali contents of fuels are generally low, but the same separation should occur. Data are needed to show the relation of alkali and acid content of stack gases to fuel composition and operating conditions.

A search for germanium in combustion products was motivated by need for the element rather than a study of air pollution, but the resulting data illustrate what may occur with minor mineral constituents of fuels. The germanium from coal ash in power plants was found to concentrate in fly ash, with practically none in slag or in stoker ash.

Other elements may be concentrated in particular product streams, depending upon conditions of release and the volatility and reactivity of individual compounds. Trace elements, such as phosphorus and arsenic, are capable of forming volatile compounds that might either escape in the gaseous form or condense on, and react with, fly ash or other solids.

Potential Line of Attack: The concentrations of various minor components of stack gases should be determined by whatever means might be applicable. The concentrations should be related to fuel analyses, to the type of equipment, and to operating conditions, excess air preheat, and furnace temperature.

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112. The Mechanism of the Transport of Toxic Fluorides in Plants.

The Problem: In recent years, injury to vegetation by fluorides emitted principally from the aluminum, steel, fertilizer, and ceramic industries has become a serious economic problem. Not only is vegetation damaged, but accumulation of fluoride compounds in forage crops has resulted in indirect damage to livestock. The complexity of the problem is well illustrated by the vast range of susceptibility among different species of plants, and even among different varieties of the same species. In gladiolus and apricot, for example 100 ppm of fluorine in the leaves may cause injury. In other plants (cotton, for instance), up to 5,000 ppm can be tolerated. An adequate understanding of fluoride toxicity to plants awaits better knowledge both of the chemistry of the fluorine compounds in the leaves and of the mechanism of transport of fluoride compound in plants, which may explain the wide range of tolerance of different species.

Potential Research Problems: It seems possible that the excess fluoride in fumigated cotton may be precipitated as calcium fluoride or aluminum fluoride, whereas in gladiolus these reactions may be limited. Analyses of the ash of these plants after fumigation may throw light on this theory. Efforts should certainly be made to distinguish between organic and inorganic fluorine compounds in the plant tissues and also between water-soluble and insoluble compounds. The rate of translocation of fluoride to the tips or margins of the leaves should be measured. These rates vary considerably among species and are an important factor in causing characteristic marginal fluoride injury. In some plants, such as corn, the injury is interveinal rather than marginal, owing presumably to slow transport to the tips and margins. It may be desirable to measure the fluoride content of cell fractions. Separation of the carbohydrate, protein, and lipid fractions could be made and then analysis made for fluoride content. Individual fluoride compounds could be determined by gas chromatography.

Another approach to the problem might make use of the camellia family of plants, which are said to absorb considerable amounts of fluoride from the soil. Tea leaves (Camellia sinensis) sometimes carry several hundred parts per million of fluorides. This material might well serve as a convenient substrate. Alternately, camellias could be grown with water-soluble fluoride or fumigated with hydrogen fluoride.

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113. How Can Dusts with Specific Characteristics be Obtained for Studies Requiring Laboratory Simulation?

The Problem: When dust hazards are submitted to laboratory investigation, the first thought of the investigator, inevitably, is how grand it would be if a series of particles in specified size ranges could be obtained. However, since particulate materials rarely occur in uniform sizes, the investigator settles for a dust cloud containing some of the desired particle sizes and many particles of other sizes. If a relatively simple procedure were devised whereby small quantities of closely-sized particles down to 0.1u diameter could be separated from a larger mass of particles, laboratory dust studies would be advanced considerably. Many other technological fields would benefit also.

The technique should not alter the particles; this means inert gases rather than liquids should be employed.

Previous Work: Classification of particles in the 10u range is accomplished industrially on a large scale, but there is little or no equipment for lower sizes. A few devices, for example the microparticle classifier (Harry W. Dietert Co., Detroit), will make satisfactory separations for a few materials down to 1u or 2u. Below this size one can now employ only liquid sedimentation or centrifugal separators, and these are often unsatisfactory because of solubility and surface-alteration effects.

Potential Lines of Attack: The Dorr-Oliver Company, Stamford, Connecticut produces midget cyclones for liquid-solid separations, and similar devices, hydroclones, have been studied by Matschke and Dahlstrom. With modifications this type of equipment might be adapted to gas-phase operation, because somewhat larger cyclones made of glass were used with fair success by McConnell for such a purpose. If inertial effects, as employed in cyclones, are to be adapted successfully, very careful attention to details of design and construction undoubtedly will be required.

A breakthrough could come, however, from a completely new development or through an ingenious engineering adaptation of some familiar principle.

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114. The Effects of Combinations of Carcinogens of Differing Structures in Experimental Animals.

The Problem: Probably the question of greatest public-health concern relating to smog is: Can the polycyclic hydrocarbons in the concentrations found at present or in the foreseeable future in smog result in human bronchogenic carcinoma? The concentrations of these carcinogens in polluted urban atmospheres have been shown to be present in vanishing small concentrations (a few tenths of micrograms/m^3). These concentrations of carcinogens may in themselves be insufficient to produce cancer, however long they are inhaled, but the necessary conditions for cancer induction are unknown. On the other hand, it has been demonstrated that the products of ozonized gasoline, presumably peroxy aliphatic compounds, organic free radicals, etc., are mildly carcinogenic in mice. Discrete chemical structures, such as butyl diepoxide and related compounds, have been experimentally demonstrated to be carcinogenic in animals. It is important to know accordingly whether the polycyclic aromatic hydrocarbons can be so fortified by carcinogens of differing chemical structure or by cancer catalysts, co-carcinogens, or cancer accelerators to result in demonstrable cancer at levels found in community air.

Background: Minimal conditions for production of cancer in man and animals are known in relatively few and unimportant instances. For example, no information is available on the minimal carcinogenic dose of 3,4-benzpyrene. Certain information is available on the relative amounts and nature of cancer catalysts required to enhance the activity of known carcinogens.

Project Procedures: There are several research problems associated with the development of major research projects on the combined effect of carcinogens that are requisite preliminaries. The first is to develop a natural means of inducing bronchogenic carcinoma in laboratory animals. Suggested methods of obtaining this first objective might be adsorption of the carcinogens on various types of carbonaceous materials, the adsorbed carcinogens to be inhaled in conjunction with an irritant of the types found in smog and capable of denuding bronchial epithelium.

The second project is to determine the minimal carcinogenic dose of polycyclic hydrocarbons required under the conditions developed in the first project.

The third project is to determine whether the effects of given doses of polycyclic aromatic hydrocarbons and aliphatic carcinogens are additive, antagonistic, or synergistic.

Outlook: 10-year period, minimum, of mature research.

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115. Rapid Estimation of the Carcinogenic Potential of Polluted Amospheres.

The Problem: Lung cancer death rates in metropolitan areas are higher than those for suburban areas, which in turn are higher than for rural areas, possibly because polluted city atmospheres contain substances that may cause cancer of the lung. The proportion of this urban excess over the expected rates for lung cancer in the United States is estimated to be from 30% to 100%. Although cigarette smoking may be somewhat higher in urban areas, it does not account for all of the excess noted. Occupational exposures have been associated with relatively few cases of proved lung cancer but this area has not been thoroughly explored. Inasmuch as lung cancer has been increasing with great rapidity as a cause of death, there is immediate need for a suitable method of rapid estimation of the carcinogenic potential of polluted atmospheres.

What Research Might Hope to Accomplish: One approach would be to determine, by some means not yet established, some earlier reactions of biologic systems which would indicate the carcinogenic potential of substances in the air. The need for this approach is apparent when one considers that man's exposure to polluted air may occur over a period of decades prior to the manifestation of cancer, even in the case of substances known to be carcinogenic. Since few animal experiments can extend over this period of time, the need for a simpler and more rapid determination of carcinogenic potential is quite great. At the present time the most fruitful line of attack would appear to be the detection of cytological biochemical alterations in animals exposed to substances known to be able to result in lung cancer. Kuschner and Nelson have made some useful observations in this regard. Tissue cultures might also be considered.

A second possible goal would be to detect new potentially carcinogenic substances. In order to do this an elaborate program of fractionating the substances extracted from polluted atmospheres and testing of these fractions in experimental animals will be needed.

Other Pertinent Considerations: This problem is one that will require many years of work, and the budget in dollars can scarcely be estimated. The analyses of polluted atmospheres and the collection of samples must obviously be carried on in places where pollution occurs.

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116. Predicting the Efficiency of a Water Scrubber for Removal of Particulate Matter from a Gas Stream.

The Problem: Scrubbers are widely used in industrial operations to remove particulate matter from effluent gas streams. Construction details and operating principles of scrubbers vary widely and their effectiveness varies considerably. Often the device chosen has very limited effectiveness on the particular aerosol involved, resulting in useless expense and inadequate air-pollution control. Generalized correlations are needed to permit the determination, in advance, of the efficiency of any scrubber in collecting any aerosol.

The State of the Art: The collection efficiency of any scrubber has a relationship to the properties of the aerosol, particularly particle size and density. The collection efficiency is high for large particles; as particle size decreases, efficiency will at first decrease slowly but then will reach a point where it will drop off rapidly. This breakpoint is a characteristic of the scrubber and usually occurs between 1 and 10u particle diameter. Few manufacturers of scrubbers provide test data for their equipment, and those that do cover only a limited range of particle sizes.

Many attempts have been made to apply theoretical principles to the prediction of scrubber efficiency. Equations involving the effects of impingement, centrifugal force, and diffusion have been developed. These equations have had a very limited usefulness, because it is seldom possible to evaluate all the factors contained in the equations. Also, most scrubbers utilize a combination of mechanisms, the interaction of which is very imperfectly understood. It appears that an empirical approach would have a greater chance of developing generalized relationships.

K.T. Semrau of Stanford Research Institute conducted an extensive literature search to obtain data with which to correlate scrubber efficiency. He correlated the data on the basis of "contacting power" and parameters characteristic of the aerosol. Contacting power is derived from gas pressure drop, hydraulic power, and mechanical power. He concluded that collection efficiency was a function of contacting power, the function containing parameters characteristic of the aerosol. The parameters used were constant only for a given aerosol, different aerosols having different parameters.

Scope of the Project: It appears that the concept of contacting power could be used to embody all the characteristics of any scrubber. The main purpose of the project would be to develop generalized correlations that would embody all the pertinent characteristics of any aerosol. The minimum characteristics that must be considered are: particle size, particle-size distribution, particle density and concentration.

A large number of experiments would be necessary, using all the principal types of scrubbers to test aerosols containing all the types of particulate matter--dusts, condensed fumes, and liquid mists. Bench-scale and pilot-plant size equipment could be used to minimize costs. Perhaps some scrubber manufacturers would make available models of their smallest commercial units.

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117. Mechanisms in the Attack of Air Pollutants on Living Organisms.

The Problem: In most cases of air pollution we know the outward biochemical symptoms, such as the yellowing of leaves and cork formation in plants, and respiratory ailments and eye irritants in animals. These are, however, end effects. In community health problems, as well as in damage to agricultural crops, we are not only interested in these end results, but in the whole sequence of reactions leading up to the readily observable effects. These effects do not express themselves in directly visible symptoms, but may lead to shortening of life or curtailing normal growth and development in both animals and plants. To study these phenomena we should know the underlying principle of the action of the foreign substance on the different parts of the cell structure.

What the Research Should Accomplish. Our problem begins when the pollutant arrives at the cell and its first defense system, often a layer of liquid of molecular dimension, containing organic and inorganic material. For example, the fine air spaces of the lungs are lined with a noncellular layer of mucoid fluid. This film alters the mechanical and electrical properties of the aqueous surface greatly. Surface tension measurements have shown that the addition of chemicals affects this behavior greatly and may halt, for example, ciliary movement or affect diffusion from the gaseous to the liquid phase. The action of air pollutants could be expected to affect the state of these interfacial films, their maintenance, and their undisturbed presence, which is essential for the proper functioning of the underlying cells. A study of the properties and the nature of air pollutants in a realistic concentration range seems to be needed.

When the material has passed the outer liquid layer it meets with the cell wall, a living part of the cell containing active enzyme systems. Its permeability is affected by the presence of foreign substances; how and to what degree is, for most pollutants, a problem worth investigating.

When the cell wall is passed, the pollutants may react with substances making up the protoplasm on any of the structures essential to life, such as nucleus microsomes and mitochondria.

The low concentrations at which toxicological and physiological effects are noticed probably indicate that we are dealing with alterations in the enzyme systems and changes in the physical state of the colloids. Only in a few cases are we able to point to the interference with a known enzyme system.

The effect of carbon monoxide consists in reducing oxygen uptake by competing with oxygen in the formation of complexes with haemoglobin. The cytotoxic anoxia effect of cyanide is due to the inhibition of oxidizing enzymes that contain iron in the ferric state, such as cytochrome oxidase. In almost all other cases of air pollutants, very little is known about the basic cause of the damage.

Experimental evidence accumulated by Dixon shows that lachrymators act on sulfhydryl groups common to a number of important enzymes, thereby inhibiting the activity of these biological catalysts.

The basic mechanism of eye irritation, as well as other physiological and toxic effects, needs a great deal more study. These investigations should include studies on mutation rates and the effects on genetic information-carrying structures such as nucleic acids.

Potential Lines of Attack: It is obvious that with the large number of air pollutants considerable specialization is necessary. After one or a group of similar substances has been selected for study, it is necessary to expose the organism to a concentration that gives toxic symptoms and to lower concentrations where no direct damage is evident. The activity of several enzymes in such a series could well be tested. The choice of the living material will differ according to the particular effects to be studied and depends somewhat on the preference of the investigator. Suitable subjects are microorganisms, which grow under established culture conditions quite readily. Any positive findings can later be tested on larger animals and plants.

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118. How May the Properties of an Air Mass be Identified?

The Problem: In the study of the environment, man is considered a receptor with a variable sensitivity, a variable reaction time, and a variable type of output. Air, although the prime constituent of the environment, serves as a medium for the care, transport, and diffusion of extraneous gases and minute particulate matter. The contributions to the environment are varied in time and space as well as in characteristics. Hence, in the analysis of air as an environment we are faced with an exceedingly complex situation where we try to find variable effluents by means of a sensor of variable sensitivity and output. The only way to do this, of course, is to replace the variable parameters with instruments of known characteristics. Much has been done in this field toward isolating noxious gases and developing adequate sensors, but the medium itself, air, has yet to be fully documented. We must be able to identify completely the physical and chemical properties of an air mass at any particular time in order to predict its subsequent behavior. Although several standard approaches are being used, the problem still remains.

Background: The analysis of air masses suffers from the enormity of the volume involved. Sensing instruments for the required parameters must be confined to relatively small areas owing to cost considerations. When cost is no object, the enormity of the physical size imposes limitations; and when this is optimized then the data reduction problem must be considered. To date there have been a few relatively large-scale micrometeorological projects (several square miles) utilizing hundreds of instruments that have produced interesting and useful data for specific areas. In general, the analyses of these data produced definitions of air mass transport mechanism for the area concerned. To translate these analyses to other areas requires conversion factors, which in themselves are subject to error. Presumably, this system implies conducting similar experiments in various "typical" areas to determine more definitely the necessary conversion factors.

What the Research May Accomplish: If the air can be identified and its characteristics known for specified changes in certain parameters, then it will be possible to predict the concentrations of various known effluents at any particular time and place. If this can be done, then any action taken will be based on positive knowledge rather than dependent on man himself to signal the time for action. This is particularly important in community planning where zoning ordinances precede development rather than the usual haphazard corrective attempts *ex post facto*.

A Method of Attack: It appears that at least one way of attacking this problem is through utilization of continuous monitoring instruments in space as well as time. The implication here is that fixed-position samplers require interpolation in space and mobile samplers, interpolation in time. A method presently being investigated is the use of special photographic techniques wherein a visible plume is monitored continuously (day and night), thereby circumventing both interpolation requirements. The results to date are promising, and since the entire operation is relatively low cost, further pursuit of this type of research is desirable.

As an analysis of air as a medium is in the realm of meteorology, all efforts along these lines must be accompanied by meteorological documentation. Unless the meteorological "boundary" conditions are known, it is difficult to generalize from the photographs. Although some meteorological parameters can be inferred from the appearance of the visible tracer, it is difficult to apply the analysis to similar conditions unless it is known what is meant by "similar conditions." Hence, a combination of the meteorological boundaries and a measurement of the transport and diffusion by visible tracers should produce as complete an analysis of the medium as can be ascertained at the present time.

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119. The Contribution of the Components of Gasoline to Possible Toxic Effects of Smog.

The Problem: It is well known that even the best internal-combustion engine emits 5.0% to 7.5% of its fuel unburned and that in the course of combustion the heat evolved results in the production of other hydrocarbon fractions that were not in the original gasoline. Today, petroleum refiners tailor gasoline to specific geographical areas and specific types of engines, and these gasolines may resemble only slightly those used in the past when active investigations were undertaken to determine their toxicity. A case in point is the high aromatic content of today's gasolines, which results from increased catalytic reforming, which in turn was occasioned by the requirement of modern engines for higher anti-knock fuels. Furthermore, a wide variety of special additives, classified as pre-ignition preventers, anti-oxidants, anti-rust compounds, anti-icing agents, upper-cylinder lubricants, and dyes for identification are present in most gasolines, in addition to the usual anti-knock fluid. Identification of the specific hydrocarbons and other combustion products in automobile exhaust and a study of their physiological properties alone and in mixtures may indicate that some of the distress produced by smog is directly related to the anesthetic properties and the hepato and renal toxicities of these compounds.

Previous Work: Boche and Quilligan recently pointed out that exposure to gasoline vapors and artificial smog decreased the rate of performance of mice in a direct relationship to the concentration of the materials in the atmosphere. Gerarde and his associates have studied the toxicological properties of a variety of hydrocarbons. Hurn and others in the U.S. Bureau of Mines have developed means of identifying the nature and amount of many hydrocarbons in fuels and in auto exhaust gases by gas-liquid chromatographic techniques.

Potential Analytical Chemical Research: Prerequisite to any pertinent toxicological studies is a knowledge of the components of auto exhaust. Although Hurn and others have developed adequate means for separating and identifying many of the lower hydrocarbons in exhaust gases, methods must be found to extend these methods to higher molecular-weight compounds that may be present in much smaller quantities than those identified to date. These methods must not only provide for the higher hydrocarbons but also for their oxygenated derivatives and the partial oxidation products of additives.

Potential Physiological Research: Gerarde's excellent studies on the toxicological properties of varius hydrocarbons could well serve as a guide to studies on those exhaust components that have not yet been subjected to close scrutiny. The use of the work test of Boche and Quilligan would aid in elucidating the contribution made by each component in gasoline to its over-all depressant action. Serial sacrifice following such exposures and histopathological examination of the internal organs might give a clue to the possible damaging effects of such exposures.

Budget for Time and Money: Research of this nature is tedious and time-consuming. The caging apparatus required for the animal work studies is available commercially, but it would be necessary to build an exposure chamber with space for fairly large numbers of animals so that many can be exposed simultaneously. Physical chemical methods for the determination of concentration in the chamber would be necessary in order that the validity of the work could not be questioned. Large animal quarters would be necessary with a constant source of mice of both sexes and probably of several strains.

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120. Can the Causes of Air Pollution Disasters of the Past Be Determined by Duplicating Suspected Atmospheric Conditions in Environmental Chambers?

The Problem: One of the most baffling enigmas of modern air-pollution investigation is the almost complete ignorance of the causes of death and illness in the famous air-pollution disasters in London (1952), the Meuse Valley (1930), and Donora, Pennsylvania (1948). Generally, the episodes had passed before very many measurements of atmospheric contaminants could be made. Measurements that were made did not show values markedly different from those occasionally found in non-lethal polluted atmospheres.

If one could reproduce the suspected atmospheres insofar as probable emissions, temperature, humidity, and the like are concerned, it might be possible to subject experimental animals to these atmospheres to determine their toxicity. It is fortunate that cattle were exposed to the London episode and that some small animals are alleged to have died in the Donora disaster. Duplication of these effects should be possible.

Historical Records: Official reports of the three disasters are available. These and several unofficial reports document the disasters as well as they ever will be. Fortunately, weather conditions and the nature of industrial and combustion processes involved are fairly well known. It should be possible, therefore, to construct a reasonable model of the polluted air masses involved and to test their toxicological properties.

Importance of the Study: Lack of knowledge concerning the important variables involved in general air pollution disasters has hindered the cause of clean air. In some cases, no action has been taken because of lack of proof of the causative agents of smog deaths. In other areas, unnecessarily restrictive laws have been invoked for the same reason.

Nature of the Research Program: A careful study of the information available concerning a specific disaster should yield adequate data on meteorological variables and probable emissions to the atmosphere. One would probably have to estimate concentrations of pollutants and use these in preliminary studies. Then, by monitoring of the atmosphere in the chamber to determine if any chemical reactions are taking place and by exposure of experimental animals, one should be able to find conditions that would approach those of the actual disasters. This finding would be a real contribution in itself, but if in subsequent studies one could remove various amounts of the several pollutants and make the atmosphere less noxious, the key to the disaster problem would be revealed.

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121. Hazards from Oxides of Nitrogen in Present and Projected Atmospheric Concentration.

The Problem: Seven oxides of nitrogen (N_2O, NO, NO_2, NO_3, N_2O_3, N_2O_4, and N_2O_5) and two hydrated oxides (HNO_2 and HNO_3) can theoretically exist in the atmosphere. The only ones present in noticeable amounts are nitrous oxide (N_2O), nitric oxide (NO), and nitrogen dioxide (NO_2).

Nitrous oxide (ca. 0.5 ppm) is a normal constituent of the atmosphere. Nitric oxide and nitrogen dioxide are pollutants. They reach the atmosphere as constituents of all combustion effluents, in concentrations ranging from less than 50 ppm in open fires to as high as 5000 ppm in automobile exhaust. Although atmospheric concentrations are usually less than 0.25 ppm, values as high as 1.86 ppm have been found in Los Angeles. Considerably higher values would probably be found in Los Angeles if it were not for the fact that NO is rapidly oxidized to NO_2 and the NO_2 reacts with olefinic hydrocarbons to produce photochemical smog. When exhaust hydrocarbons are radically diminished, as required by the new California Motor Vehicle Pollution Control Law, this outlet for removal of atmospheric nitric oxide will no longer exist. A fear arises, therefore, as to a build-up of nitrogen oxide concentration and its effect on people.

Physiological Research: NO_2, to which NO emissions to the atmosphere are eventually transformed, is a highly toxic gas, which can produce delayed pulmonary edema. The maximum allowable concentration (MAC) for 8-hour exposures in factory atmospheres is 5 ppm. This value is based on evidence that an exposure of this duration and concentration produced decreased pulmonary function in animals. Considerable information is needed on the mechanism responsible for delayed edema, its relationship, if any, to chronic changes in the lung from repeated exposures, and the permissible concentration below which susceptible individuals suffer no chronic difficulties.

A fruitful area for biochemical research is the reaction between nitric oxide and hemoglobin. *In vitro*, a very stable compound of nitric oxide and hemoglobin is formed. Methods of determining the existence of this compound or the reaction product of NO_2 and hemoglobin *in vivo*, if they exist, could be useful as an indicator of exposure to oxides of nitrogen.

Plant Research: Only a few studies have been made on the effect of nitrogen oxides on vegetation. Wild mustard was found to be a fairly susceptibe indicator plant, but no information has been reported on economic crops. The likelihood of increasing atmospheric concentrations of oxides of nitrogen in the future makes further investigation on the amount, nature, and mechanism of vegetation damage imperative.

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122. The Control of Oxides of Nitrogen.

The Problem: Nitric oxide and nitrogen dioxide are fast becoming more suspect as likely health hazards in urban communities. As major precursors to photochemical smog, they are already a nuisance in West Coast cities and occasionally in other cities throughout the world. In fact, one of the means seriously considered in California for control of smog was abatement of oxides of nitrogen emissions from automobile exhaust. Unfortunately, however, nearly half of the nitrogen oxides reaching the Los Angeles atmosphere comes from non-automotive sources, principally power plants, furnaces, boilers, and, in smaller amounts, from all other combustion processes.

Actually the concentration of nitrogen oxides (principally nitric oxide) is quite low (less than 300 ppm) in most combustion effluents. They are a problem only because of the tremendous volume of stack emissions in most urban communities. No control method is currently available.

Previous Work: Most studies of nitrogen oxide abatement have been directed toward effluents of comparatively high nitric oxide content (over 1000 ppm), such as auto exhaust and the tail gases from nitric acid manufacturing units. Catalytic decomposition of NO to nitrogen and oxygen and catalytic reduction with methane, carbon monoxide, hydrogen, etc., have proved effective on tail gases and are under investigation for auto exhaust treatment. The restriction of peak flame temperatures in the internal-combustion engine by operation with rich mixtures, injecting water into the cylinder, and recirculating exhaust gases has also been proposed for elimination of nitric oxide from auto exhaust. A West Coast public utility has also been partially successful in reducing nitric oxide emissions from a large power plant by changing the location of secondary air ports.

Lines of Attack: The tremendous volume of stack gases and the low concentration of nitric oxide in them almost obviates any treatment method requiring gas-liquid contact or temperature change. Catalytic decomposition of NO is a possibility, but most suitable catalysts are oxygen-sensitive and thus not applicable. Methods that theoretically would be most economic are those that would prevent or inhibit nitric oxide formation, or, since nitric oxide is unstable at ambient temperatures, would hasten its decomposition. Better knowledge of the factors affecting nitric oxide formation during combustion could furnish leads as to suitable methods of inhibiting its formation.

There is also the alternate approach, often considered and as often discarded, of adding a neutralizing or deactivating agent to the stack gases as they are emitted. Although most proposed additives have created a greater problem than the one for which a solution was sought, the possibility of adding a neutralizer to the stack gases is intriguing.

An entirely different approach could be directed toward burner and combustion box design to eliminate hot spots, which some engineers believe are responsible for most of the nitrogen fixation in normal combustion processes.

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123. The Design of Environmental Chambers to Duplicate Polluted Atmospheres.

The Problem: The atmosphere, even under relatively stable conditions, is a dynamic mass subject to many macro- and micrometeorological influences. Studies of polluted atmospheres yield a great deal of information, but because of the great number of uncontrolled variables extrapolation of data from one locality to another or from one time to another is hazardous. The experimental scientist insists on having control of at least the most important variables before he is willing to accept deductions drawn from a series of measurements. Not being able to control variables in the ambient atmosphere, he resorts to a chamber or model that simulates a part of the atmosphere and may be subjected to control. Experience has shown that most environmental chambers only partially duplicate atmospheric conditions, although the reasons for this departure are not always apparent. Accordingly, there is a need to determine how the variables inherent in the design and operation of environmental chambers affect the validity of relating chamber data to the ambient atmosphere.

Previous Work: Most of the environmental chambers that have been built recently have been designed in such a way that pollutants in near-atmospheric concentrations could be subjected to irradiation with real or simulated sunlight. Chambers that have been described in some detail are those operated by Stanford Research Institute, the University of California at Los Angeles, Robert A. Taft Sanitary Engineering Center, and the Los Angeles County Air Pollution Control District. These chambers vary in size, materials of construction, type and source of illumination, and method of operation. Each installation was frankly the result of a compromise, partially because of budget limitations but largely because of the pressure for results.

The Research Approach: Everyone who has ever operated an environmental chamber can prepare a list of things that would be done differently if a new chamber were to be built. Each has his own ideas, but most recommendations fall into categories, e.g., materials of construction, surface-volume ratio, method of introducing pollutants, and method of simulating meteorological variables. Each of these variables could well be the subject of an independent study. Obviously, the degree of difficulty among the several categories will vary greatly, but eventually further information on all of them from various pollutant systems will be required.

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124. Are Air Ions Important In Environmental Health?

Background: It is a meteorological fact that the atmosphere carries a variable electrical charge in the form of ionized particles. Ions of molecular size, called small ions, usually carry a negative charge. These small ions are continually being created and destroyed; their lifetime varies from a few seconds to several minutes. The ions are created by cosmic rays and radiation from radioactive materials in the earth and in the air. They are destroyed by various mechanisms, including neutralization by pollutants. High concentrations of negative ions are usually associated with "healthy" air, i.e., air over the oceans, in the high mountains, over large forests, and near waterfalls. Large ions with a positive charge, usually condensation nuclei, are associated with polluted air. One method by which small ions are destroyed is by attachment to these positive ions.

A great many proposals have been made from time to time to increase the negative-ion control of the ambient atmosphere to improve general health. Although many of these have been of a magicianwith-a-black-box variety, some have been made by reputable organizations that have the public welfare in mind. Unfortunately, there is no irrefutable evidence that negative ions have any effect on health or well-being one way or the other. What is needed is a well-planned research effort by a competent medical and biological scientist. Such an undertaking will require considerable courage, because a great many scientists look on negative-ion therapy as bordering on charlatanism. For the same reason, research funds to underwrite pertinent studies may be difficult to obtain.

Previous Work: Despite the suspicious character of the claims that benefits to health may be achieved from the use of negative ions, there has been some work reported that indicates there may be a basis for these claims. Krueger, at the University of California, exposed tracheal strips from experimental animals to positive and negative ions. The former decreased ciliary rate and mucous flow; the latter accelerated the rates. This may explain the reports of almost miraculous effects of negative ions on asthma and hay fever sufferers. Reports have also been made by competent scientists of the use of negative ions to control lung cancer and to aid the healing of burns. Several industrial concerns have jumped the gun and have incorporated electrostatic ion generators into air-conditioning units. The fact remains, however, that high-grade biochemical and clinical work is needed to substantiate or to dispel the many claims made for atmospheric ions.

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125. Mechanism for the Removal of Sulfur Dioxide from the Atmosphere.

The Problem: Sulfur dioxide has been involved in the majority of the air pollution disasters of the past 50 years. Unfortunately, very few data on atmospheric concentrations just prior to or during a disaster are available. Conjectured concentrations of SO_2 were far below that which could conceivably cause even slight distress, much less serious illness or death. Accordingly, it has been postulated that atmospheric sulfur dioxide was converted to SO_3, H_2SO_4, various sulfites and sulfates, or possibly just concentrated by absorption on aerosol particles.

Knowledge of the mechanism by which sulfur dioxide is removed from the atmosphere would throw light on those compounds which could be responsible and thus direct toxicologists and medical scientists in their research on health effects of pollutants. Lack of information also allows zealots to promote hysteria, which, in turn, forces passage of unreasonable and punitive legislation.

Previous Work: Several mechanisms for sulfur dioxide removal from the air have been proposed based on laboratory experimentation. Johnstone has suggested that SO_2 is absorbed by water droplets containing oxidation catalysts and then oxidized and hydrated to SO_3 and H_2SO_4 respectively. Hemeon has suggested that SO_2 may be converted first to an alkali sulfite and then oxidized. Chambers, Foter, and Cholak analyzed the particulate matter collected from the atmosphere of several American cities and showed that the final state of sulfur could well be as the sodium salt. Work at Stanford Research Institute on the effect of sulfur dioxide on the photochemical reaction between olefinic hydrocarbons and nitrogen dioxide indicates that an organic sulfur compound may be one of the constituents of the photochemically produced aerosol. Whether all of these reactions take place in the air, or none at all, is an important consideration in devising control regulations for sulfur dioxide emissions.

Nature of Research Needed: Probably the best way to attack the problem is by the surveillance of actual polluted atmospheres. There are many urban communities where this might be done many times during the heating season. It should probably be backed up by studies in controllable atmospheres, to which SO_2 could be added either by itself or as a constituent of combustion effluents. Either study might well require more sophisticated analytical procedures than those currently in use. Undoubtedly the problem is difficult, but it nonetheless requires an early solution.

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SECTION II. FOOD SCIENCE AND TECHNOLOGY

Problem No.	**Title**
201	Changes in the Chemistry of Flavors Caused by the Processing of Foods.
202	The Nature of Toxic Materials in Plant Enzymes.
203	Food Intoxication and Infection Associated With Poultry Products.
204	Psychrophilic Spoilage of Foods.
205	Objective Methods For Determination of Quality in Meat.
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201. Changes in the Chemistry of Flavors Caused by the Processing of Foods

The Problem: Foods undergo chemical changes in the flavor components during heat processing and thereby lose some of their original fresh flavor and appeal to the consumer. The problem occurs to a variable degree with different foods but is very widespread. For example, the flavor in canned green beans differs considerably from that of the fresh vegetable. Such chemical changes in flavor undoubtedly affect food acceptance and intake by the consumer. Our knowledge of the chemical changes that occur in flavor during processing is pitifully meager. Yet these changes are extremely important to the satisfaction and welfare of the individual eating them. There is some indicationg that flavor plays a role in nutrition, and therefore may be related to the total nutritional value of the food. Furthermore, since the poor acceptance of certain heat-treated foods sometimes results in a very low intake of the particular food, some have speculated that undesirable constituents may form as a result of processing. Since most of the foods we eat are treated with heat to one degree or another, it is extremely important that investigations relating to the effect of heat on the chemistry of flavor be undertaken.

Background Information: Once the compounds responsible for flavor changes are characterized, effective means can then be sought to control them. This knowledge may lead to new equipment development, improvement in conventional methods of food handling and processing, changes in the method of storage, or possibly the development of new methods of preservation.

Possible Lines of Attack: In view of the new developments in gas chromatography, it is now possible to follow some of these changes very effectively. There are a number of possible lines of attack. One approach would be to study the effect of heat processing on chemical changes occurring in the volatile flavor constituents. This could be done by the use of chromatographic procedures. A second approach, and particularly an important one with respect to protein foods, such as poultry and meats, would be to study the relation of heat processing to the changes in amino acids, proteins, carbohydrates, lipids, etc. It is well known for example, that the flavors of broiled, fried or roasted chicken are all different and without doubt, different compounds and perhaps, different quantities of these compounds are formed depending upon the cooking procedure used.

Still another approach would be to study the degradation of sulfhydryl compounds (including amino acids, peptids, and proteins such as beta lactoglobulin and albumins) with a possible development of undesirable flavors. The latter type reactions are well known in heat treatment of milk and milk proteins.

It also would be of interest to study the breakdown products resulting from the heat processing of lipids, such as carbonyls, which in turn can undergo aldol condensations or other chemical browning type reactions with nitrogen compounds.

Special Requirements: In pursuing this problem, it would be necessary to have a well-equipped biochemical laboratory with gas chromatographic equipment.

References:

1. Shallenberger, R.S., Pallesen, H.R., and Mayer, J.C., Food Technology **13**, 92 (1959).
2. Advisory Board on Quartermaster Research and Development, Committee on Foods, May (1957).
3. Boyd, E.N., and Gould, I.A., J. Dairy Science **40**, 1294 (1957)

202. The Nature of Toxic Materials in Plant Enzymes.

The Problem: Plant enzymes such as papain, ficin, bromelain, and urease are being used increasingly by the food industry. The enzymes are concentrates of all of the soluble materials which are present in the starting plant. In addition to the desirable enzyme action for which they are used, the preparations frequently contain undesirable constituents which have markedly irritating effects upon humans. For example: crude ficin contains a material which is so irritating that some food industries prefer not to use this valuable enzyme rather than run a risk to the health of workers. Urease contains an associated material which is so powerful the laboratory workers who grind the jackbeans may expect to become ill unless very stringent precautions are used to exclude all traces of the plant material from the air.

Background Information: The general aim of a research project in this area would be to establish the identity of materials associated with the enzyme preparations, responsible for the irritating side effects, but which are not part of the actual enzyme. A second portion of a research project might concern itself with methods that could be used effectively to separate the undesirable materials from the enzyme preparation. A third portion of the problem could be to identify the pharmacological effects of adventitious materials.

There has been extremely little work on the identification of contaminating materials in the enzyme preparations currently in use. The majority of the work has been laboratory investigations of the purification of the enzyme, without particular reference to industrial application or to the nature of the contaminating substances.

Possible Lines of Attack: The methods for the purification of the enzymes have been well developed. Such methods, however, are not involved with the identity of the contaminating materials, the by-products of the purification, which are of concern in this problem. These materials could be identified by chemical, toxicological, and pharmacological means. The compounds are thought to be relatively small molecules which should be susceptible to chemical identification.

Special Requirements: No special equipment or situations would be needed for this project since it would involve straightforward chemistry and biochemistry.

References: **References:**

1. Ullman, S.B., "The Inhibitory and Necrois-inducing Effects of the Latex of *Ficus* Carica L", Expt. Med. and Surg., **10**, 2 (1952).
2. Schwimmer, S., and Pardee, A.B., "Principles and Procedures in the Isolation of Enzymes", Adv. Enzymol. **14**, 375 (1953).

203. Food Intoxication and Infection Associated with Poultry Products.

The Problem: Foods consisting entirely or in part of poultry products are frequently involved in food intoxications and the poultry components are likewise considered as sources of organisms causing these intoxications. Over the past several years there has been a substantial increase in the use of poultry products, particularly prepared and precooked items such as stuffed turkey, chicken pies, and salads.

These and other items can be important reservoirs of *Salmonella* and other organisms of considerable importance to public health.

Background Information: There is a need for the development of culture media and techniques designed for the isolation of *Salmonella* and other organisms from poultry products. It is true that studies on these organisms occurring in poultry products have been made over the past many years, but the techniques used have been borrowed to a large extent from medical bacteriology and are frequently not suitable.

Possible Lines of Attack: The proposed study would involve a comparison of microbiological media and techniques so that eventually standardized methods for investigation would be established.

These tests would not only involve isolation of the organisms, but development of techniques for making rapid counts. Organisms to be considered would be *Salmonella, Staphylococcus*, fecal streptococci, and coliform bacteria.

With the development of such techniques and information concerning the occurrence and number of organisms present, it should be possible to take steps toward establishing standard methods of examination, correlate sanitation to product safety, pinpoint sources of contamination, and establish tolerances for products in general.

Standard bacteriological laboratory equipment and facilities would be required for such work.

References:

1. Felsenfeld, O., Young, V.M., and Yoshimwa, T.A., J. Am. Med. Assoc. **116**, 17 (1950).
2. Walker, H.W., and Ayres, J.C., Poultry Science **38**, 1351 (1959)

204. Psychrophilic Spoilage of Foods.

The Problem: Perishable foods that must be held under refrigeration are highly susceptible to microbiological activity. Despite the widespread use of refrigeration, the bacteriological spoilage of low-acid foods such as meat, fish, and milk products and their markedly short shelf-life, still seriously limits their market distribution and consumption. In many instances the product that reaches the consumer is either in the incipient spoilage stage or it has a very short shelf-life left. The consumer often discards the food materials either completely or when partially used.

Background Information: The spoilage of refrigerated foods is caused by a wide heterogeneous group of microorganisms commonly referred to as psychrophiles. These organisms (bacteria, yeasts, and molds) are capable of good growth at temperatures below 5 degrees centigrade in a relatively short period. They will form colonies on solid media visible to the naked eye within two weeks at 0 degrees C.

The literature is relatively replete with information about the characterization and identification of organisms of this type. There is, however, relatively little effort being devoted to the study of the quantitative physiology of psychrophiles in foods susceptible to their growth and biochemical activities. Before low-temperature spoilage of foods can be effectively controlled, the biochemical activity, the kinetics of growth, and the effects of various processing treatment upon such kinetics and activities must be known.

Possible Lines of Attack: In order to study the low-temperature spoilage of foods effectively, it is necessary that the activities of the various microorganisms be delineated prior to the evaluation of methods of control. As a first approach, an initial screening of the spoilage potential of the readily available strains of microorganisms on food samples can be studied. Following this evaluation, the growth kinetics of each potentially active strain might be determined. The biochemical activities of significance for spoilage could be studied involving different foods and different test organisms. An important portion of the general problem is the organoleptic qualities imparted to the foods by the spoilage organism. The effect of processing variables and packaging techniques as related to low-temperature spoilage can be studied. The action of antimicrobial additives at low temperatures also requires investigation.

Special Requirements: The special requirement for an investigation of this type is the ready availability of a food-processing laboratory capable of simulating commercial conditions, storage facilities for food products at low temperatures, and a well-equipped microbiological laboratory.

References:

1. Brown, A.D., and Wiedemann, J.F., "The Taxonomy of the Psychrophilic Meat-Spoilage Bacteria: A Reassessment", J. Appl. Bacteriol., **21**, 11 (1958).
2. Ingraham, J.L., and Bailey, G.E., "A Comparative Study of the Effect of Temperature on the Metabolism of Psychrophilic and Mesophilic Bacteria," J. Bacteriol., **77**, 609 (1959).
3. Ingraham, J.L., and Stokes, J.L., "Psychrophilic Bacteria", Bact. Rev., **23**, 97 (1959).

205. Objective Methods for Determination of Quality in Meat.

The Problem: Although a substantial portion of our diet consists of meat, there is at present no satisfactory objective procedure for measuring the quality attributes such as tenderness, juiciness, and flavor. Development of objective procedures for these purposes would be of tremendous direct value to the research scientist, consumer, and processor. Most certainly it would be a guide for the consumer insofar as preparation and utilization of meat are concerned.

Background Information: At present, methods for measurement of tenderness include determining the force required to shear a cylinder of meat, or the energy required to grind a definite quantity of meat or to chew a piece with the use of an instrument equipped with artificial dentures. The correlation of results obtained with the Warner-Bratzlar shear machine and taste panel determinations of tenderness is quite good for cooked meat, but unsatisfactory for raw meat.

Attempts have also been made to correlate the amount of pressed fluid or electrical conductance with juiciness of meat, with very limited success. It is apparent that an entirely new approach is needed to solve this problem.

Possible Lines of Attack: A suggested approach to this problem is through the use of new chemical techniques. Experimental work to determine the chemical substances in meats that may correlate with flavor is expanding and is clearly a frontier in food science. At present, there is no known chemical constituent of raw meat that is associated with flavor of cooked meats. Undoubtedly, several substances are involved and new laboratory techniques such as the use of gas chromatography may be valuable in this regard. The ingenuity of the food scientists will be put to the full test in this field of detecting microquantities of material associated with food flavors.

Special Requirements: The equipment needed for such work would be that ordinarily found in food science laboratories plus gas chromatography, and meat tenderometer testing equipment.

References:

1. Schultz, H.W., "Mechanical Methods of Measuring Tenderness of Beef", Proceedings of Reciprocal Meat Conference, Chicago, (1957).
2. Hamm, Reiner, "Biochemistry of Meat Hydration", Proceedings of the Eleventh Research Conference, American Meat Institute Foundation, p. 17, (1959).
3. Wierbicki, Eugen, and Deatherage, F.E., "Determination of Water-Holding Capacity of Fresh Meats", J. Agric. & Food Chem. **6**, 387 (1958).

206. The Evaluation of Frozen Fish Quality.

The Problem: At the present time, moderately satisfactory tests are available that will provide a fair indication of the quality of fresh fish. Frozen fish, on the other hand, are extremely difficult to judge as to quality. The only tests that have been suggested for the frozen product are subjective ones and it is a fact that frozen fish are presently being accepted or rejected on the basis of odor. The grading of fish by this extremely crude procedure occasionally limits severely the availability of fish products, and consequently unnecessarily increases the cost of such protein. On the other extreme, the method may reduce the quality of the fish available to the market, and so develop a reluctance on the part of the consumer ever to purchase fish products.

Background Information: The quality of fish, frozen or otherwise, is decreased by either bacteriological or chemical spoilage. The net result of spoilage is the accumulation in the flesh of compounds that may be considered undesirable flavorwise. The accumulation of these compounds arising from bacteriological action is different from the accumulation attributable to chemical reactions. It has been difficult, therefore, to develop a test that will measure incipient spoilage objectively. Some methods have been developed but they have not been used since they are either too involved to be carried out on a routine basis or the methodology differs depending upon the area of the fish sampled. These methods were developed a number of years ago, prior to the availability of many of the present chemical techniques.

Possible Lines of Attack: A general approach to the problem of evaluating frozen fish quality could be to identify the compounds which accumulate either by bacteriological or chemical action in fish, and relate these compounds quantitatively to the organoleptic changes taking place in the flesh. The compounds that might be used as indicators of quality must be developed or utilized by the chemical or microbiological activities in all parts of the fish in approximately the same concentration. The indicator compounds must not be subject to leeching or seasonal variations, and must not be affected by the area from which the fish is taken.

Thus an investigation of organolepticly active compounds occurring in fish should be undertaken. Secondly, if the presence and concentrations of such compounds can be established under different storage conditions, tests should be developed that will indicate their presence or absence or when they occur in minute quantities. It is presumed that some of the new techniques such as gas chromatography, paper chromatography, etc., may lead to a partial solution of the problem.

Special Requirements: No special equipment other than that required for microchemical analysis is required for this investigation. A source of supply of fresh and frozen fish, however, is required.

References:

1. Lang, V.W., Farber, L., Beck, C., and Yerman, F., "Determination of Spoilage in Protein Foodstuffs With Particular Reference to Fish", Ind. Eng. Chem., Anal. Ed. 16,490 (1944).
2. Reay, G.A., and Shewan, J.M., "The Spoilage of Fish and Its Preservation by Chilling", Ad. in Food Res., Vol. II, Academic Press, Inc., New York, New York, (1949).

3. Proctor, B.E., Nickerson, J.T.R., Fazzina, T.L., Ronsivalli, L.J., Smith, R.K., and Stern, J., "Rapid Determination of the Quality of Whole Eviscerated Haddock", Food Tech. 13:4, 224 (1959).

207. Coagulase Positive *Staphylococci* in Precooked Frozen Foods.

The Problem: There is a lack of information concerning the proportion in precooked frozen foods of coagulase-positive *Staphylococci* which are enterotoxic types. There is a need for the clarification of the significance of coagulase-positive *Staphylococci* in food products as a possible cause of *Staphylococci* food poisoning and especially at the present time in precooked frozen foods. The relative number of coagulase-positive *Staphylococci* which are enterotoxic types is not known.

Most frozen foods are non-sterile and may contain significant numbers of *Staphylococcus* organisms. When such foods are thawed and held at temperatures approaching 50°F., growth is likely, but this may or may not lead to the formation of *Staphylococcus* poison. The development of the toxin is dependent upon the presence of organisms capable of producing such toxin and at the present time there is little information upon the proportion of *Staphylococci* normally found in food materials capable of producing the toxin.

Background Information: At the present time, the only test for enterotoxic *Staphylococci* is the determination of coagulase-positive *Staphylococci*. This test is extremely difficult to apply routinely. There is no simple method, although several tests are available to determine the numbers of coagulase-positive *Staphylococci* present.

Phage typing may be used as a method of determining the enterotoxic organisms, but it is tedious in the extreme and cannot be used as a routine test.

Possible Lines of Attack: An evaluation of coagulase-positive *Staphylococci* in precooked frozen foods by phage typing would help establish the significance of the coagulase-positive test and provide a basis for suitable standards. Information is also needed upon the degree to which enterotoxic *Staphylococcus* will develop in unsterile precooked foods held at temperatures above 50°F. This information could also be used for establishing standards.

Special Requirements: No special equipment is needed for an investigation of this type other than that readily available in bacteriological laboratories. Standard samples of precooked frozen foods would be needed so an investigation of this type would best be carried out in cooperation with a food technologist, who has access to experimental processing equipment.

References:

1. Dack, G.M., "Food Poisoning", Third Ed., The University of Chicago Press, Chicago, 251 pp., (1956).
2. "Conference on Staphylococcal Infections", Editorial, J. Am. Med. Assoc. **166**, 1177 March 8 (1958).
3. Smith, Ian MacLean, "Staphylococcal Infections", The Yearbook Publishers, Inc., Chicago (1958).

208. Protein Differences in Different Varieties of Wheat.

The Problem: World population is increasing steadily and adequate food production in many countries is becoming a matter of wide concern. Meat eventually will become a luxury item if not an accoutrement and cereals will constitute an increasing proportion of diets in many countries. The nutritional quality of cereals, such as wheat which is adapted to growing over a tremendous area of agricultural land, will therefore become even more important than it is at present. The general studies on wheat quality that have been conducted so far are generally related only to the baking quality of wheat flour. Studies of composition have largely concerned themselves with the protein only as it is related to the baking quality. The results of these investigations, however, have not contributed to any better understanding of the relations concerned. Therefore, the problem is twofold: The relation of the quality of the protein in cereals to nutrition and the relation of the composition to baking quality.

Background Information: There is extensive work already reported in the literature concerning the quality of wheat and flour as related to baking. In this area of investigation it has been established that the percentage composition of individual amino acids in the protein is not related to baking quality. Furthermore, it has been extremely difficult to define the protein fractions which are isolatable from flour protein gluten. The fractions which have been isolated appear to depend upon the methods used for their isolation.

Possible Lines of Attack: The most obvious line of approach to this problem is to study methods of characterizing the various protein constituents of gluten in order to derive specific proteins of unambiguous nature. The individual isolated proteins could then be used to study their contribution to baking quality as well as to nutrition. In order to establish the characteristics of the fractions isolatable, it is necessary that they be pure and that they be homogenous. Therefore, the methodology which has been used for the isolation of animal and other plant proteins must be applied to the problem.

Special Requirements: The requirements for this work are easily met in laboratories equipped for biochemical work in the protein field. No special equipment or facilities other than those normally present in such laboratories is required.

References:

1. Kent-Jones, D.W., and Amos, A.J., "Modern Cereal Chemistry", The Northern Publ. Co., Liverpool.
2. Miller, Byron S., and Johnson, John A., "A Review of Methods For Determining the Quality of Wheat and Flour for Breadmaking", Technical Bulletin #76, Kansas Agr. Expt. Station, April (1954).

209. The Fate of Agricultural Chemicals Used in Animal Feeds.

The Problem: Chemicals such as antibiotics, hormones, tranquilizers, drugs, and trace elements are added to animal feeds for various nutritional and medical purposes. There is an urgent need for reliable information as to how much each animal food additive is finally ingested by humans in milk, eggs, or meat. Of equal importance is knowledge of the form in which the chemical exists when ingested.

This problem is apart from that of the cumulative effect of digested products containing additives upon the human. It is quite possible that many of the products which are used in animal feeds never appear in the same form in the meat of the animal as when ingested by the animal.

Background Information: Considerable work has been done to show the beneficial effects of antibiotics, hormones, and other compounds in feed regimes. Quite a number of compounds have recently been listed as "allowed" by the Food and Drug Administration in animal feeds. Presumably the compounds, if they appear in the flesh of the animal or in its products, can exert negligible influence on the human or else the compounds do not persist in the animal tissue. Some compounds which are known to persist in the milk from dairy cows are prohibited by the FDA and a zero tolerance allowed in milk. Examples of these compounds are penicillin, neomycin, hydrocortisone, and diethyl stilbestrol. The last named is allowed in beef and sheep feeds but not in milk. These compounds are passed through the body of the animal essentially unaltered and so can be detected in the animal products.

Only some of the antibiotics fed to poultry appear in chicken flesh and eggs. Others have not been found. Conceivably they are so altered in the body that their identity is destroyed but it is conceivable that the altered compounds could have physiological effects.

Possible Lines of Attack: The approach to the solution of this problem would rest in the ability to so label ingested compounds that they, their derivatives, or their breakdown products might be observed in the final animal product. Carbon 14 could be utilized by the synthesis of specifically labeled compounds or by the use of compounds uniformly labeled, thus allowing recognition of the parent compound or the altered compounds. The compounds which might be detected through the labeling experiments would need to be identified by conventional organic means. The physiological effect of altered compounds would have to be observed by long-term feeding experiments upon other animals.

Special Requirements: In order to carry out this investigation, a laboratory should be equipped for radioactive work as well as for the synthesis of labeled compounds. The investigator would also require ready access to animals in order to conduct conventional toxicological investigations. Normal organic laboratory equipment would suffice for the rest of the work.

References:

1. "FDA Action Regarding Diethylstilbestrol", Amer. Feed Mfgrs. Assoc. Bull., General Circ. U-42, Dec. 11, (1959).
2. Briggs, George M., "Estrogen Residues in Meat-Public Health Aspects", J. Amer. Med. Assoc., **164**, 1473 (1957).
3. Cover, M.S., Ludwig, D., and Waller, E.F., "The Levels of Various Antibiotics in Serum and Tissues of Chickens Following Administration at Therapeutic Levels", Poultry Sci., **35**, 1139 (1956).
4. Title 21-"Food and Drugs", Chapter I-"Food and Drug Administration, Department of Health, Education and Welfare", Subchapter B-"Food and Food Products", Part 121-"Food Additives, Subpart C-"Food Additives Permitted in Animal Feed or Animal Feed Supplements", Subpart D-"Food Additives Permitted in Food for Human Consumption", Federal Register.

210. Enzymatic Discoloration of Shrimp.

The Problem: A major factor in the spoilage or loss of quality of frozen shrimp is a discoloration of the surface resulting in blackened areas near the segments. In extreme cases, the entire surface is blackened with exudation of an inky liquid. Such undesirable changes may occur even in shrimp that has been adequately refrigerated, especially if the heads are not removed soon after they are caught.

Background Information: The condition involving discoloration is called "black spot". It is believed to result from the action of the enzyme tyrosinase, which brings about the oxidation of tyrosine and related substrates and their eventual polymerization to dark melanin pigments.

The only reliable measure which has been widely used to prevent such discoloration is dipping shrimp in sulfide solutions. While this procedure is very effective, it is not desirable. Since the cooking time for shrimp is short and the pH is rather high, much of the sulfite remains in shrimp tissue after cooking. This residue, without doubt, affects the eating quality of the product. More important, however, is the fact that it destroys thiamine, a fact which is undesirable from the standpoint of nutritive value. Furthermore, in practice the sulfide is applied by fisherman on shrimp boats. Often used in excessive quantities, it is easily detectable by the sulfurous odors given off.

Other chemicals, such as ascorbic and citric acids, have been tried as dips and covering solutions but have not proved successful under practical operation.

It is evident that a new approach is needed for this problem. More basic research on the distribution of the enzymes and substrate in the shrimp is needed, but evidence now available indicates that the enzymatic reaction is confined to the outermost layers of the shrimp just beneath the chitenous shell.

Possible Lines of Attack: It should be possible to inactivate the enzyme by brief heat treatments, sufficient to denature a thin layer on the outside of the animal. Hopefully, this could be accomplished without cooking the shrimp to such an extent that much shrinkage or coagulation occur. A suggestion therefore is that a study be made of the possibility of surface pasteurization. It might not only be effective in controlling discoloration but would likely reduce the number of surface bacteria and hence, bacterial spoilage. Such a procedure might be an alternative approach to the growing demand of the use of antibiotics and other products as preservatives for shrimp and fish.

Special Requirements: The equipment and facilities required for such studies would be those ordinarily found in a well-equipped food science laboratory.

References:

1. Fieger, E.A., "Numerous Publications on Shrimp Preservation", (1950-1960).
2. Faulkner, M.B., et al, "Enzymatic Darkening of Shrimp", Food Res. **19**, 1 (1954).

211. Retention of Beverage Quality in Preserved Milk Products.

The Problem: For the last several centuries efforts have been made to provide milk in the human diet under all circumstances. Presently available preserved milk products, such as sweetened condensed milk, were developed as a result of efforts to prolong the life of milk so that it might be used when fresh milk might not be available. With modern-day pasteurization and refrigeration processes, the keeping quality of milk has been substantially increased. However, the costs of transporting such milk to the ultimate consumer is high and it would be desirable to develop sterilized or dried products, which when reconstituted to the normal solids content, would be acceptable as beverages.

Background Information: The conventional products of industry, such as dried skim milk, condensed milk, and evaporated milk, are not too satisfactory as beverages. The concentrated products have a strong cooked flavor and the dry products have a chalky or oxidized flavor. The keeping quality of these preserved milk products is generally poor.

Efforts have been made to concentrate or freeze milk, but with limited success since even milk stored at temperatures as low as -20 degrees F is subject to protein denaturation.

Concentrated milk that has been sterilized undergoes off-flavor development and protein denaturation. Fat separation is also a problem. Dried whole milk is extremely unstable and rapidly undergoes deteriorative changes even when packed under nitrogen gas. Reconstitution of such products is poor even when fresh.

The general approach to the solution of this problem lies in a better understanding of the changes which take place upon the deterioration of the various preserved milk products. The nature of the protein denaturation, its kinetics, and its mechanism must be understood before we can expect great progress toward prevention. Changes taking place in the protein of milk upon drying must be understood from a basic point of view.

Possible Lines of Attack: General approach in this case is thus a basic study of the biochemical and biophysical properties of the various milk constituents and study of the changes taking place upon treatment of the individual materials. Further, a study should be made of the possible interactions of the constituents as they exist in the fluid product.

Special Requirements: The facilities required for this investigation are those possessed by a well-equipped biochemical laboratory. A milk processing laboratory would, however, be required in conjunction with this study to supply typical processed milk products for study. This requirement is particularly important since changes taking place occur rapidly and must be studied in some cases during the actual processing.

References:

1. Gammack, D.B., and Weckel, K.G., "Effects of Two-Stage Sterilization on the Physicochemical Properties of Evaporated Milk", J. Dairy Sci. **40**, 1570 (1959).
2. Giroux, R.N., Calbert, H.E., and Swanson, A.M., "A Study of the Processes of Gelation, Flocculation, and Caramelization as Related to Heat Stability in Concentrated Milk", J. Dairy Sci. **41**, 710 (1958).
3. Hartman, G.H., and Alstrand, D.V., "Ultra-high Temperatures, Sterilization and Aceptic Canning of Concentrated Milk with Pilot Equipment", J. Dairy Sci. **41**, 711 (1958).

212. The Organic Chemistry and Colloidal Characteristics of Hydrocolloid Vegetable Gums.

The Problem: Although vegetable gums are used very extensively by the food industry, very little is known of the chemical and physical properties of these important food items. In view of their extensive use, it is urgent that information relating to the chemical and physical nature of these substances be obtained.

Background Information: It is estimated that more than a billion pounds of vegetable gums are used in the United States alone each year. The methods of use are largely those of an art rather than chemistry or food science because of the lack of information concerning the basic nature of vegetable gums. It is apparent that the utilization of these complicated polysaccharide polymers will increase as soon as their chemistry and colloid phenomena are more fully understood. In the minds of industrial people who use them, the hydrocolloid gums are hydrophyllic molecular weight compounds, usually with colloidal properties, which under certain conditions produce gels, highly viscous suspensions, or viscous solutions of low solids content. Thus, the term "gum" is applied to a wide variety of substances of gummy characteristics and cannot be precisely defined.

The various gums differ greatly in their mode of action. For example, quaran and locust bean gums are quite similar in their molecular structure, yet quaran is readily soluble in cold water while locust bean gum is not. Certain of the gums have specific properties which render them particularly useful in certain foods. Thus, quince seed gum will alter the degree of agglomeration in casein particles in milk.

Some gums are linear in structure, whereas others consist of the branched chain molecules. It is possible to alter the functional groups in both types of gum to achieve a desired result. Such manipulations, however, are limited.

Certainly there are possibilities for expanding the existing gums into further application in foods by developing a greater knowledge of the mechanism of their action.

Possible Lines of Attack: The approach to such studies would involve organic chemical procedures with the view of determining the molecular characteristics of the particular gum. Other physical procedures would be used to determine the physical characteristics.

Special Requirements: Such studies would require a well-equipped organic laboratory with apparatus for physical measurements.

References:

1. Steiner, A.B., and McNeely, W.H., "Organic Derivatives of Alginic Acid", Industrial and Engineering Chemistry **43**, 2073 (1951).
2. Whistler, Roy L., and Miller, James N.B., "Industrial Gums", Academic Press, New York (1959).
3. Whistler, R.L., and Smart, C.L., "Polysaccharide Chemistry", Academic Press, New York City (1953).
4. Garing, D.A.I., "Effect of Hydrogen Ion Concentration on the Viscosity and Electrophoretic Mobility of Solutions of Sodium Carageenate", Jour. of Colloid Sci. **9**, **141** (1953).

213. Flavor Reversion in Oils.

The Problem: Certain fats after undergoing refining treatment and thus being rendered flavorless and odorless by steam deodorization can develop objectionable odors through oxidation in times far short of that required to produce rancidity. The flavor and odor changes occurring in such fats are termed "flavor reversion."

The fats subject to this flavor change generally contain appreciable amounts of linolenic acid or other fatty acids with more than two double bonds. They include all marine oils, linseed oils, soybean oil, and rape seed oil. The problem is most acute in soybean oil because of the large quantities of this oil being used for edible purposes. The reverted flavor and odor is unpleasantly accented when the fat is heated to high temperatures.

Background Information: The mechanism of reversion is not understood. While reversion of an oil is considered to be due to an oxidation process, no data are available as to the exact amount of oxygen required to produce flavor reversion in any particular fat. It is certain, however, that the amount is extremely small, probably not more than a fraction of that necessary to produce rancidity in fats. The work that has been done in the area has in general yielded contradictory results. While oxidation appears to be involved, reversion is not eliminated by hydrogenation to a point where all unsaturated fatty acids have disappeared. The reverted flavor of a hydrogen oil usually bears little resemblance to that of the same oil before hydrogenation, and it is probable that reversion is fundamentally different in the two cases. Altogether, it may be said that the phenomenon of reversion constitutes one of the chief puzzles of present-day chemistry.

Possible Lines of Attack: An approach to the solution of this problem might be made from a number of avenues: (a) the isolation and identification of the flavor materials occurring in reverted oils, (b) the isolation and identification of the components which could give rise to the objectionable odors upon oxidation, and (c) a study of the mechanism of degradation of linolenic acid from a flavor viewpoint combined with a kinetic study using the same means of analysis. It is quite possible that all of these approaches would require the use of microtechniques such as gas chromatography, paper chromatography, infrared equipment, etc.

Special Requirements: The only special facilities outside of a well-equipped organic chemistry laboratory for this study, would be the availability of organoleptic panels for the study of the development of reversion flavors.

References:

1. Durkee, M.M., "Soybean Oil in the Food Industry", Ind. Eng. Chem. **28**, 898 (1936).
2. Robinson, H.E., and Black, H.C., "Flavors in Food Fats", Ind. Eng. Chem., **37**, 217 (1945).
3. Bailey, Alton E., "Flavor Reversion in Edible Fats", Oil and Soap **23**, 55 (1946).
4. Markley, Klare S., "Edible Soybean Oil Products", Interscience, New York, Chapter XIX.

214. Inhibitors of Digestive Enzymes in Foods

The Problem: The importance of the maximum efficiency of the dietary utilization of foodstuffs and feedstuffs is self-evident. The utilization of food materials is directly dependent upon proper digestion in the alimentary tract. Proper digestion, in turn, is dependent upon the existence of active digestive enzymes. There is extremely little knowledge available about the presence, in foods, of agents which inhibit or retard the action of these digestive enzymes. In addition, new processing methods or even presently existing processing methods make contributing agents capable of inhibiting or accelerating the digestion of the food materials. The presence of adventitious chemical compounds in foods, which may be added inadvertently or intentionally, also can contribute to a decrease in the activity of digestive enzymes.

Background Information: The important enzymes, proteinases, carbohydrases, and lipases, can be inhibited or retarded by many chemical and biochemical agents. The specific inhibitors of the proteinases have been characterized from several sources. These include the inhibitors of trypsin and chymotrypsin from lima beans, soybeans, and egg whites. There is evidence that the inhibitors obtained from different individual species differ considerably in their activity. Only limited studies under restricted conditions have been done on the importance of these inhibitors in the digestion and utilization of protein.

Evidence has also been presented for the existence of an inhibitor of amylase in cereals.

There is no information concerning the inhibition of lipases by compounds present in food materials.

Possible Lines of Attack: The approach to this problem would, of necessity, include a fundamental study of the biochemistry of presently recognized inhibitors of protelytic enzymes. A survey would be necessary to establish the presence of inhibitors of the various digestive enzymes in different foods. The effect of processing upon the inhibitory substances found naturally would be required. Foods of various classes would need to be examined after processing by various techniques for inhibition of digestive enzymes. Since this field has not been exploited to any extent, the approaches outlined above constitute only a few of the possible lines of attack.

Special Requirements: Facilities that would be required for this investigation would be confined primarily to biochemical equipment although the availability of test animals might be required.

References:

1. Dixon, Malcolm and Webb, Edwin C., "Enzymes", Academic Press Inc., New York, N.Y., (1959).
2. Kneen, E., and Sandstedt, R.M., "Distribution and General Properties of an Amylase Inhibitor in Cereals", Archives of Biochemistry, **9**, 235 (1946).
3. Rhodes, M.B., Nelle, Bennett, and Feeney, R.E., "The Trypsin and Chymotrypsin Inhibitors From Avian Egg Whites", Journal of Biological Chemistry, **235** (1960).

215. Effect of Pesticide Application on the Nutritional Value of Plant Products.

The Problem: The use of chemical pesticides on plants can be expected to continue to increase in the future. Extensive studies have been conducted on the effect of these pesticides on the biology and biochemistry of insects, fungi, other plant pests and on animals. However, the effect of agricultural chemicals on foods produced by plants has received relatively little attention. Extensive work is urgently needed in this area.

Background Information: The slight knowledge that we have in this area is concerned almost entirely with herbicidal action. It reveals that the vitamin and mineral levels may be significantly affected so that even the content of components such as protein and specific carbohydrates may be altered.

The practical importance associated with a consistent decrease in nutrient levels is obvious. We are concerned that with the improvement of the following techniques, we may be affecting to some extent the nutritional values of certain foods. Importance of any consistent increase in nutrient levels might prove to be an even greater significance from both the practical and fundamental viewpoints. Our basic national interest lies not only in the growth of more abundant crops but also in the production of higher ratio of nutrients to total food weight. The ratio has been examined in relation to soil fertility, water, genetic background, and many other factors, but almost never with regard to the effects of treatment with small amounts of synthetic chemicals. Compounds that could increase the nutrient ratio would be both commercially attractive and of great scientific interest.

Possible Lines of Attack: It is apparent that extensive research in this area is needed. At the outset, the required approach appears to be a broad but simple analysis for specific nutrients in genetically defined crop lands grown under standard conditions. In order to obtain results that will have the most practical significance, commercial pesticides and plant species having the greatest economic importance would be investigated under conditions which usually apply in the field.

In other cases, a more closely controlled approach might be taken in which the plant material is grown in the greenhouse or phytotron under controlled conditions of light, temperature, soil, water, and minerals which are repeatedly reproducible. Severe limitation of plant type, sample size, and normal climatic factors would be balanced by the benefits of continuous year-round experimentation, simplification of the experimental system, and reduction of variable factors. Undoubtedly both the practical and laboratory approaches will be necessary for clarification of this problem.

Special Requirements: Facilities needed for this type of investigation are those normally used by a biochemist or organic chemist or perhaps a plant physiologist. Equipment, including that for microbiological assay, and auxiliary space for plant growth and treatment, would be necessary.

References:

1. Sell, H.M., et al, "Changes in Chemical Composition of Stems of Red Kidney Bean Plants Treated With 2, 4-D", Plant Physiol., **24**, 295 (1949).
2. Luecke, R.W., "Effect of 2,4-D on the Vitamin Content in Stems and Leaves of Red Kidney Bean Plants", Plant Physiol., **24**, 546 (1949).

216. Determination of Keeping Quality of Fresh Fish.

The Problem: Many tests have been proposed for the determination of the freshness of fish, but none of them will indicate how long the relative freshness may be expected to persist under standard storage conditions. Such a test is urgently needed.

Background Information: Fish deterioration occurs almost imperceptibly at first, but when the incipient spoilage stage once takes place, a very rapid increase in the accumulation of spoilage products occurs in a very short period of time. Almost all known chemical tests for freshness, therefore, are of little value in predicting keeping time. If fish is consumed past the point of incipient spoilage, most certainly palatability and possibly safety suffer. In some cases, especially if pathogenic bacteria may be present and if the product is to be consumed with very little cooking, (as with fishsticks, shellfish, precooked frozen fish products), a definite potential health menace may exist.

Food Science research has resulted in the development of a satisfactory accelerated test for the keeping quality of oils. These tests are generally based upon heating either of thin layers of the oil, or oil through which air is passed. Tests for the measurement for rancidity in which the induction time is estimated are also used. They are used as measures of keeping quality. Similar tests for bacterial spoilage have not been developed or even attempted because of a possible alteration of the pattern of spoilage bacterial growth, which would result from the use of increased incubation temperature for the fish sample.

Possible Lines of Attack: One approach to the solution of this problem might be to follow a procedure analogous to the test used for the stability of oil whereby fish would be incubated at a high temperature to accelerate the spoilage rate. However, success of such a procedure is unlikely.

A more promising line of attack would be to correlate bacterial and chemical tests, making use of the view that keeping quality would be greatest for samples having both very low bacterial contamination and chemical test values.

Another point of experimentation would be to study the changes that may occur before the accumulation of spoilage bacteria products. Such changes might be as follows:

(1) Physical changes, such as electrical conductivity of muscle,
(2) Chemical tests, such as accumulation of certain non-protein nitrogen fractions that form at an early stage and from some cause other than bacterial spoilage, and,
(3) Biochemical tests for enzyme-like activity which might decrease during the post-mortem period.

Special Requirements: A well-equipped biochemical laboratory will be required, as well as a reliable source of fresh fish.

References:

1. Cutting, C.L., "Changes in the pH and Buffering Capacity of Fish During Spoilage", Journal of the Science of Food and Agriculture, **4**, 597 (1953).
2. Shewan, J.M. and Jones, N.R., "Chemical Changes Occurring During Spoilage of Chilled Fish and Their Relation to Freshness Tests", Chemistry and Industry, **27**, 713 (1956).
3. Stansby, Maurice E., "Problems in Determining Fish Freshness", Food Technology **12**, 260 (1958).
4. Tarr, H.L.A., "Microbiological Deterioration of Fish *Post Mortem*, Its Detection, and Control", Bacteriological Reviews, **18**, 1 (1954).

217. Paralytic Shellfish Poisoning

The Problem: Certain shellfish growing on the Pacific Coast, such as the butter clam *(Saxibomus nuttali)*, has not been utilized because of the sporadic and variable occurrence of shellfish poisoning caused by a dinoflagellate.

Background Information: The particular microorganism involved is *Gonyaulax catenella* which is associated with the so-called "red tide." This dinoflagellate occurs in certain clams, mussels, and other shellfish that grow along the Pacific Coast from California to Alaska.

Unless some procedure can be worked out for protection against this poisoning, a great food reservoir is unavailable. Furthermore, it is apparent from the standpoint of public health, that the problem is an extremely important one. It is urgent, therefore, that a procedure be worked out for protection against this type of poisoning.

In Alaska, it may occur at any time in the year, but it is highly variable with respect to time and place. In California, and on the Atlantic Coast, on the other hand, the toxicity of shellfish occurs at specific times and particularly during the appearance of so-called "red tides". It is necessary that an improved and rapid chemical method for assaying the toxic component be developed. Finally, an accurate method for determination of toxic levels of the poison is needed.

Possible Lines of Attack: In studying such a problem the first phase would involve the relation of environmental conditions to oceanographic, biological, and biochemical factors in the sea and soil in the vicinity of toxicity to shellfish. The second phase would be the development of chemical methods for determination of toxicity. The third phase would be concerned with the possibility of altering the safe level for ingesting the poison.

Special Requirements: A biochemical laboratory associated with a laboratory that is equipped for toxicological studies. A seashore location would be most advantageous.

References:

1. Chambers, John S., and Magnusson, Harris W., "Seasonal Variations on Toxicity of Butter Clams From Selected Alaska Beaches", Special Scientific Report, Fisheries No. 53, Fish and Wildlife Service, U.S. Department of the Interior, August (1950).

2. Medcof, J.C., "Paralytic Shellfish Poisoning on the Canadian Atlantic Coast", Bulletin, Fisheries Research Board of Canada, **75** (1947).
3. Schantz, D.J., et al, "A Procedure for the Isolation and Purification of the Poison From Toxic Clams and Mussel Tissue", J. Am. Chem. Soc. **79**, 5230 (1957).
4. Tennant, A.C., Naubert, J., and Corbeil, H.E., "An Outbreak of Paralytic Shellfish Poisoning", Canadian Medical Assoc. **72**, 436 (1955).
5. McFanen, E.F., Schafer, Mary L., Campbell, Jeptha E., Lewis, K.H., Jensen, E.T., and Schantz, E.J., "Public Health Significance of Paralytic Shellfish Poison", Advances in Food Research, **10**, 135 (1961).

218. The Mechanism of the Inactivation of Phosphatase in High-Temperature, Short-Time Pasteurized Milk

The Problem: Phosphatase tests have been recognized as standard procedures to detect inadequate times and/or temperatures in the low-temperature pasteurization of dairy products. Investigators have found that after processing milk at high temperatures and ultra-high temperatures for short times, a positive test does not necessarily indicate pasteurization. Dairy products treated by these newer procedures may have a negative test immediately after pasteurization but positive test after storage depending upon time and temperature. The samples that possess this peculiar characteristic may either be sterile or have low bacterial counts and therefore, positive results cannot be attributed to bacterial phosphatase. Since the developed phosphatase reacts similarly to normal alkaline phosphatases of raw milk and cream, its presence has been termed "reactivation" of the milk phosphatase activity. It should be of great interest to investigate the mechanism by which there is an apparent regeneration of an enzyme system in an essentially non-metabolic media.

Background Information: There are many advantages commercially to the utilization of high-temperature short-time pasteurization; the product is generally of better quality, the process equipment is simpler, the equipment is easier to clean and maintain in a sanitary condition, and it is more easily adaptable to varying flow rates of products. Since the standard method to detect under-pasteurization depends upon the phosphatase tests, such tests in this case may be invalid and consequently, new procedures should be developed. Several alternative tests have been proposed. Siegethaler proposed a differentiation test based upon the differences in time for the inactivation of the regenerated phosphatase versus the native phosphatase when heated to 55 degrees centigrade for 5 minutes. The reactivated phosphatase inactivates more rapidly than the original system in the milk. Other tests have been proposed for determining the pasteurization of milk processed by the H-T S-T method, but the problem of the mechanism of the inactivation and regeneration of the enzyme system has not received a great deal of attention.

A number of theories have been advanced regarding the reactivation of enzymes following heat treatment. Albers claimed that certain phosphates are dissociated into the apoenzyme and the co-enzyme under reducing conditions. Presumably, the enzyme would be reactivated by a recombination of the apoenzyme and co-enzyme by reversion of the denaturation of the protein, formation of a new coenzyme and/or the formation of a new link between the two components after pasteurization. Several other investigators have postulated possible reasons for the reactivation although the problem is by no means solved.

Possible Lines of Attack: In order to understand inactivation-reactivation phenomena, one of the approaches to the problem might be the isolation of both the original phosphatase and the reactivated phosphatase and their comparison structurally, and chemically. Others might be the careful study of the kinetics of the reactivation-deactivation phenomena and the study of the kinetics of the native phosphatase versus the reactivated material.

Special Requirements: Facilities required for an investigation of this type are to be found in biochemical laboratories equipped for enzyme work. It would be advantageous in such an investigation to have readily available equipment for the high-temperature short-time sterilization of milk in order to produce at will the reactivated system. Isolations of the compounds could be done from raw milk and that processed in the laboratory.

References:

1. Morton, R.K., "Purification of the Enzyme Alkaline Phosphatase of Milk", Biochem. Jour., **55**, 795 (1953).
2. Albers, D., "Die Vollstandige Trennung der alkalischen Nierenphosphatase in Protein und prosthetische Gruppe, II Mitteilung", Hoppe-Seyler's Zeits. fur Physiol. Chemie **261**, 269 (1939).
3. Schwimmer, S., "Regeneration of Heat-Inactivated Peroxidase", J. Biol. Chem. **154**, 487 (1944).

219. Methods for Assessing the Toxicological Properties of Food Additives

The Problem: Food additives must now undergo long expensive tests before they are permitted to be used in foods. These tests are of long duration and are so expensive that improvement in nutrition, and general increases in the available food supply are greatly inhibited. This investigation would be directed toward the development of short-period tests for determining the safety of new chemical additives.

Background information: At present the tests for safety involve the use of long-term animal feeding experiments. If there is a possibility of carcinogenesis, then at least two species of animals must be used. It would be highly desirable, therefore, to develop a procedure whereby reliable tests or at least presumptive tests for safety might involve the use of microorganisms or enzymes. Since the toxicity of a food additive may be manifested in changes in the activity of one or more enzyme systems, it may be possible to assess the toxicological effects of food additives by measuring their effect directly on the enzyme systems. It thus may be possible to work out bacteriological enzyme systems eliminating the animal feeding studies entirely. Alternatively, the changes in activity of enzyme systems in various tissues after a short-term animal feeding experiment may be measured.

Possible Lines of Attack: Proposed research, therefore, should be aimed primarily at correlating the toxicological effects of additives observed in long-term feeding experiments with those observed on various enzyme systems in tissues and in the pure form. Detailed techniques would have to be worked out, since this is truly a pioneering area.

Special Requirements: The equipment and facilities required would be those ordinarily found in biochemical and food-science laboratories. In addition, an animal colony would also be required.

References:

1. Colowick, S.P., and Kaplan, N.O., "Methods in Enzymology", New York, Academic Press, Inc.
2. Nord, F.F., "Advances in Enzymology", Interscience Publishers, Inc., New York.
3. "Appraisal of the Safety of Chemicals in Foods, Drugs and Cosmetics", Association of Food and Drug Officials of the United States, (1959).

220. The Relation of Slaughtering Practice to Pork Meat

The Problem: The increasing problems of respiratory disease of swine is a matter of considerable significance to the national health. It is important that methods and procedures be worked out so that, at the time of slaughter, infected animals can be easily perceived.

Background Information: The major infections of swine include brucellosis, salmonellosis, toxoplasmosis, enterovirus, leptospirosis, and trichinosis.

There is an increasing tendency in the swine industry to house large numbers of animals in small areas. This practice has many unfavorable implications from the standpoint of environmental health. Recent surveys of slaughtered hogs at several large packing plants indicated that between 20 and 65 per cent of all animals examined had pneumonic lesions. Furthermore, pleuropneumonia-like organisms are increasing in importance as positive agents of pericarditis, pleuritis, and arthritis. The handling of infected hog carcasses evidencing no easily detectable lesions in the packing plant poses a serious problem. In the past, these carcasses were marketed and consumed without further attention. It seems desirable that public-health officials be provided with more information concerning the survival time of the organisms in meat and that the veterinary inspectors have additional information that will allow them to safeguard the wholesomeness of pork and pork products. Handling of infected and normal carcasses interchangeably by workers presents a problem in the health of the workers. The consumption of the meat by the public is perhaps of even greater concern.

Viewed from the esthetic point of view, the merchandising of meat containing harmless but undesirable abscessed material or arthritic joints creates considerable resistance and repulsion on the part of the consumers.

Possible Lines of Attack: One of the first objectives in studying this problem is to find some satisfactory method of growing the etiological agents. Even though it has been demonstrated that most transmission of respiratory diseases of swine is by the air and that these diseases are among the most common of swine, there is still no good means for identifying many of them. More adequate procedures need to be developed for the detection of species of brucella, salmonella, leptospiro, erysiplothrix, and toxoplasma. Surveys of packing plants during the handling of contaminated meats would be required to detect concentration of these organisms. These investigations would involve the use of standard bacteriological procedures and possibly the development of new ones. Following the surveys, studies would have to be made on methods of detection and procedures developed for use in packing plants.

Special Requirements: In carrying out such work standard microbiological, parasitological, and food science laboratories would be needed.

References:

1. "The Science of Meat and Meat Products", American Meat Institute Foundation, Avi Publishing Co., Inc., Westport, Conn., (1960).
2. Hull, Thomas G., "Diseases Transmissible from Animals to Man", C.C. Thomas, Springfield, Ill.

221. Salmonella in Egg Products

The Problem: *Salmonella montevideo* has been found to occur in egg whites in prepared cake mixes, and *Salmonella reading* in a nationally distributed food in Alaska. The latter apparently was responsible for an outbreak of illness in children. The occurrence of

Salmonella in significant numbers in various products containing foods is an extremely important problem and one that should receive attention. It is very important that a method be evolved for treating egg products to render them safe from salmonellosis. *Salmonella irumu* has been observed to occur in frozen eggs in South Africa and it was considered to be the cause of diarrhea in one individual. The patient recovered and returned to work in a restaurant as a food handler and subsequently, innoculated foods that passed the disease to other people.

Background Information: In 1960, the Health Department in Los Angeles reported that three members of a family became ill 16 to 21 hours after eating in a public cafeteria. The symptoms were those characteristic of *Salmonella* and the food item eaten was a cream puff, shared by three people. Stool specimens from two of the individuals and four of the 20 food handlers were positive for *Salmonella typhimurum.*

Infections such as those observed in South Africa and Los Angeles appear to be occurring more frequently and most certainly too often. The need for a method of protecting the public against the occurrence of these infections in egg products is urgent. There seems to be promise that some sort of gaseous sterilization might be applicable to dried egg products. Any ideas for treating frozen egg products in the undried state should be tried. Studies are needed not only to develop a method of eliminating the organism but also to be certain that any process developed will not adversely affect the physical characteristics of the processed egg. Pasteurization or storage at very high temperatures for a considerable period of time apparently reduces the number of *Salmonellae*, but it does not eliminate them. This means, therefore, that sufficient numbers may remain so that infections may occur.

Possible Lines of Attack: Gaseous sterilization has been studied to a limited extent with ethylene oxide and beta propiolactone. Studies should be conducted with these compounds. At the present time, some work is being done with beta propiolactone, which does not have the penetration of ethylene oxide. Nevertheless, further studies should be undertaken. Other chemicals should also be considered if they appear suitable for this type of operation.

Tumbling equipment has been developed for powers and with this type of manipulation it may be possible to overcome the limited penetration affect of beta propiolactone.

References:

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2. "Morbidity and Mortality Weekly Report", U.S.P.H.S., National Office of Vital Statistics.
3. LoGrippo, G.A., and Rupe, C.E., "Hepatitis Frontiers", Little Brown and Company, Boston, Chapter 32 (1957).

222. The Rancidification of Cooked Ham Fat

The Problem: When ham is cooked and exposed to the air, it gradually becomes rancid even when stored at temperatures below -5° F. The rancid flavor is encountered primarily in the fat portion of the ham, and in time it reaches a condition where the meat becomes undesirable and eventually inedible.

Background Information: The commercial distribution and eventual storage in the home of precooked hams is increasing. Since the fat may undergo deterioration all the way along the line, it results in a decrease in palatibility, loss of food, and sometimes distress upon eating. The rancidification can be controlled by the complete elimination of oxygen. This method of control, however, is not a satisfactory solution because of the difficulty in insuring the permanence of an inert atmosphere during shipment and storage.

Possible Lines of Attack: The suggested studies, therefore, would be pointed in another direction toward identification of catalytic materials which must be present in the ham and their elimination. A second line of research would be to find a practical way of introducing an antioxidant into the ham fat.

The first approach would involve the isolation and identification of the accelerators, by the use of chemicolor biochemical procedures. This step could be followed by a study of the kenetics of the oxidation reaction. The second approach would involve the finding of a suitable antioxidant and a practical method at application.

Special Requirements: The equipment and facilities required for such studies are those ordinarily found in a biochemical and food-science laboratory.

References:

1. Kemp, James D., McCampbell, Harry C., and Grainger, Robert B., "Procedure for Sampling and Laboratory Rendering of Ham Fat and Characteristics of Hams and Fat During Aging", Food Technology, June (1957).

223. The Proportion of Our Food Protein Actually Available for Bodily Nutrition

The Problem: Over a period of years, the raw protein content of our common foods has received extensive investigation and evaluation. However, the results of this work generally have been based on nitrogen analysis, a value which actually has only qualitative relation to nutritive value. Recently, much of this work has been repeated or extended with emphasis on the amino-acid content. Certainly the new information is of much greater value in assessing the amounts of these essential dietary components presented to the individual. On this inadequate basis, it has been estimated that only about 10% of the people of this country receive protein supply below the recommended level.

Background Information: An enormous and all-important difference may exist between the protein composition of foodstuffs in the market and the amounts and proportion of amino acids digested and made available for metabolism. First, very little of our best protein source, meat, is eaten raw, most of it being subjected to varying degrees of heat treatment ("cooking"). What little we know about the effects of this treatment on the component amino acids indicates that many of them are, like certain vitamins, destroyed or altered to a considerable extent. For example, it has been shown that over 70% of the essential amino acid "threonine" available from pork is lost upon heating. Since heating free amino acids *in vitro* leads to extensive decomposition based on both general structure (decarboxylation, condensation, racemization, and deamination) and specific functional groups (dehydration, hydrolysis, desulfurization, etc.), it is to be expected from the very nature of the compounds involved that the threonine example will not be an isolated case.

Second, knowledge of the digestibility of protein, either cooked or raw, and the extent to which the resulting amino acids become available for use in the body is almost non-existent. However, it safely may be presumed that extensive alteration results at the usual cooking temperatures, including stereochemical changes, reactions and degradation of side-chains, and destructive depolymerization.

Adequate protein nutrition is of utmost importance to the people of our own country and to those of other countries. Although the quantitative requirements for the intake of dietary amino acids are becoming known for man and his domestic animals through the use of "ideal" synthetic diets, information regarding the extent to which these requirements actually are satisfied in everyday life has not been forthcoming. This hiatus may be due in part to previous difficulty in the quantitative determination of amino acids and in part to the slow acceptance of modern analytical methods in this branch of nutritional science. In any case, it would appear that such data represent a fundamental step toward supplementation of deficient diets, correlation of diet to the incidence of disease, and, perhaps, to broad social effects not now fully anticipated.

Possible Lines of Attack: Comparison of the amino-acid composition of the protein of meat, as well as other common foods, before and after cooking, could now be improved greatly by advances in quantitative analysis based both on microbiology and ion-exchange chromatography. The very limited investigation of this subject in the past has been conducted principally by chemical methods, which should be reevaluated and extended by present improved techniques.

For the broadest application to public health, the standards established for the type of meat to be evaluated and the temperature and duration of heating should be closely related to those in most common use by the consumer. A vast amount of this type of information has been accumulated by the U.S. Department of Agriculture, particularly through the Institute of Home Economics and the Household Economics Research Division of the Agricultural Research Service. This information could form a reliable basis for further laboratory investigation.

It would be of considerable interest to determine *in vitro* the effect of standard cooking practice on amino-acid content as an initial measure of nutrient loss. Since we are not even well aware of the result of heating on mixtures of pure amino acids or peptides, a chemical study of this process might be in order at the outset.

In vitro study of the differences observed in the action of proteolytic enzymes on heated and unheated "standard meat protein" would provide evidence of reduction (or increase) in the availability of specific amino acids. By proper choice of enzymes and conditions, such information might help to form a basis for correlation of heat treatment with protein nutrition.

The only really satisfactory and practical way of obtaining such correlation, however, must be based on direct measurement of the degree to which amino acids and peptides enter the blood stream following protein ingestion. Although no work has been done along this line in humans, an excellent start has been made by workers at the E.I. DuPont laboratories, where changes in the amino-acid content of dog plasma have been measured at intervals following consumption of a "synthetic" diet. While it is possible that the results of many such measurements eventually might be related to those obtained *in vitro*, as mentioned previously, it is probable that the only true measure of protein nutrition will be found to involve amino-acid levels in human blood following ingestion of a realistically prepared diet.

Special Requirements: The proposed attack would require the services of nutritionists, biochemists, or organic chemists, and laboratory facilities for conducting analytical work and any necessary experiments with animals. Assistance in statistics, physiology, and medicine also should be available.

References:

1. Longenecker, J.B., and Hause, N.L., "Relationship Between Plasma Amino Acids and Composition of the Ingested Protein", Arch. Biochem. Biophys., **84**, 46 (1959).
2. "Nutritive Value of Cooked Meat", Nutrition Revs., **17**, 32 (1959).
3. "Utilization of Proteins (effect of heat)", Nutrition Revs., **17**, 92 (1959).

224. The Contamination of Shellfish by the Virus of Hepatitis.

The Problem: Shellfish have long been indicted as vectors of bacterial pathogens such as typhoid bacilli. Recently, however, strong evidence has arisen that shellfish also transmit the virus of infectious hepatitis. Research data are needed on the accumulation and survival of hepatitis virus in various kinds of shellfish, and on the relation between sewage-polluted waters and the occurrence of hepatitis virus in shellfish.

Background Information: The role of oysters as vehicles for the transmission of hepatitis virus from sewage-polluted waters was demonstrated firmly during an epidemic in Sweden in 1955-56. More recently (January 1961) outbreaks of infectious hepatitis in Pascagoula, Mississippi and in Troy and Mobile, Alabama were definitely traced to oysters harvested from sewage-polluted waters near Pascagoula. Finally, there is strong epidemiological evidence that much of the endemic occurrence of hepatitis along the eastern seaboard is attributable to the consumption of raw or partially cooked clams.

Sanitary control of the shellfish industry is maintained by the USPHS working closely through state health departments. This control is based on the "1959 Manual of Recommended Practice for the Sanitary Control of the Shellfish Industry." Growing areas are classified by the coliform concentration of overlying waters. An attempt has also been made to establish bacterial standards for the shell liquor or meat of shellfish, but to date this effort has not been successful. Coliform concentrations in the meat of oysters from approved growing areas often exceed 16,000 per 100 grams, the tentative limit for acceptance. The fact that USPHS standards for drinking water require a coliform concentration less than 1 per 100 ml while 16,000 coliforms per 100 grams of oyster meat is an acceptable concentration seems incongruous, to say the least.

It is recognized that the feeding mechanisms of clams and oysters tend to concentrate bacteria from the overlying waters. It is also known that these bacteria will survive in the oyster meat and shell liquor for many weeks, especially when the live oyster is refrigerated. Virtually nothing is known about the occurrence of hepatitis virus in sewage-polluted estuaries or the accumulation and survival of such viruses in the various species of shellfish.

Possible Lines of Attack: One method of approaching this problem would be to conduct a virological survey of sewage-polluted waters where shellfish grow. This survey might establish a relationship between the concentration of virus (and bacteria) in the overlying water and the concentrations in the shellfish. The survival of hepatitis virus in the shellfish might also be determined by assaying contaminated animals after various intervals of storage. These *in situ* investigations leave much to be desired, however, because of the lack of control of many variables.

A more logical approach would be to place oysters of various ages in trays through which water of controlled temperature and salinity is passed. (See Problem 225 for more details of artificial culture). To this water, known concentrations of coliforms and hepatitis virus could be added. Then, the accumulation of each organism in the oysters after a given period of exposure could be measured. Contaminated oysters could also be transferred to unpolluted water to determine the rate and extent of self-cleansing. Any ingenious investigator can think of numerous modifications and extensions of this plan of attack.

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225. The Artificial Cultivation of Oysters in a Controlled Environment.

The Problem: Contaminated oysters are a major problem of environmental health. Oysters are significant sources of endemic and epidemic gastrointestinal disturbances, owing to the nature of their feeding process, to their affinity for sewage-polluted waters, and to the fact that many of them are eaten raw or only partially cooked. Without the rigid control of USPHS and state health personnel of the gathering and interstate shipment of shellfish, oyster-borne enteric disease would erupt in many serious outbreaks. The problem could be obviated to a large extent if oysters could be spawned, grown, and harvested in a controlled environment. Indeed, such "farming" should prove highly profitable, as well as beneficial to health and nutrition.

Background Information: Oysters such as *Crassostrea gigas* discharge many thousands of eggs each year, but relatively few of them survive through the larval stage to set as spat, owing primarily to predation in the highly competitive environment. The spat and adult oysters, in turn, are sensitive to predators such as the Japanese drill and the starfish, to parasites such as pathogenic protozoa, to changes in salinity and temperature, to industrial wastes, and to alterations in the food chain on which they subsist. It is contended that less than one oyster reaches adulthood for every million eggs.

While oyster biologists have accumulated extensive information relative to the effects of predators, parasites, salinity, and industrial wastes, very little is known about the nutrition of oysters. Some biologists believe that diatoms and other algae constitute the major source of nourishment because complete forms are found in the alimentary tract and diatom tests are found in the feces. Other competent biologists believe that flagellates of various types and perhaps small crustacea are the principal food. No one, apparently, has conducted extensive tests with single foods or combinations to determine the optimum diet for shell growth and fattening.

Oysters are grown and harvested under very primitive conditions. They are subjected to all of the natural predators and diseases; to the whims of tides, salinites, and temperatures; and to uncertain food supplies. Oyster culture today is analogous to animal husbandry in the days when chickens scratched for all their food in the barnyard and hogs wallowed in the mudhole and rooted in the open fields or woods. Today, chickens are hatched, raised, fattened on controlled diets, and marketed without touching soil and often without seeing real daylight. Hogs are reared on concrete platforms that are kept almost immaculate and they are fed balanced, nutritious, and fattening diets.

There is no fundamental reason why oysters could not be cultivated in similar indoor farms. The water supply could be filtered and perhaps chlorinated to remove all pathogens, then adjusted for salinity and temperature. Female oysters can be made to eject their eggs under controlled conditions, the eggs can be fertilized artifically, and millions of them developed as larvae and spat without interference from predators. The larvae can be made to set and the spat can be transferred when large enough to trays or to a mesh of suitable material where the young oyster can receive clean water of proper salinity and temperature. Disease, predators, and pollutants can be eliminated. It will be necessary, however, to add to the water a suitable food, or combination of substances, to meet the nutritional requirements for fast growth and good meat. The big question is to determine what artificial foods are nutritious and economical. Once they are known, oysters can be farmed as carefully as chickens, and perhaps as profitably. Moreover, the public-health menace of oysters from contaminated natural waters would be mitigated.

Possible Lines of Attack: This problem is one that many oyster biologists are competent to handle. That they have not done so previously is probably attributable mostly to shortages of funds, facilities, and personnel; but it may be due in part to the fact that no agency or group has pushed for an answer to the major problem of oyster nutrition. Before oyster farming under artificial conditions is feasible, we must know what the creatures eat; what is the real nourishment and what is so much roughage; what is best for shell growth and what is best for fattening. Finally, we ought to discover the exotic substances of low cost that can be substituted for diatoms and dinoflagellates. Will oatmeal or wheat grains suffice or could finely ground hamburger be used? Can organic industrial wastes such as bloodmeal or other slaughterhouse products be used. Would sterilized activated or digested sludge be suitable?

For a specific plan, it is suggested that young adult oysters be kept in multiple trays, in accordance with techniques developed by Loosanoff and others at Milford, Connecticut, or by Dimick at Oregon State College, and that water be passed over them under controlled conditions of temperature and salinity. The water should first be filtered and then dosed with varying concentrations of specific foods. One tray of oysters, for example, might receive a pure culture of a brown diatom; another tray a pure culture of a green alga; another a dinoflogellate, another a protozoan or small crustacean, others might get mixtures of two or three organisms. The growth, fatness, glycogen, and other parameters of condition should be measured periodically, and the feces and pseudofeces weighed and examined microscopically. In this manner, by replicate and repeated tests, it should be possible to determine which natural foods are best for oyster culture.

With this information in hand, it should be possible to proceed to artificial foods of vegetable and/or animal origin. Multiple tests of many possible exotic materials should soon reveal the most nutritious and yet economical foods.

Requirements: Research of this nature is tedious and time-consuming. It must, of necessity, be performed at a seaside location, preferably in oyster-growing areas such as New England, the Chesapeake Bay, the Gulf Coast, or the Pacific Northwest. Owing to the growth characteristics of oysters, many years will be required for a full development of the research. There are several existing laboratories where such work could be performed, but they might have to be enlarged considerably.

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SECTION III. OCCUPATIONAL HEALTH

Problem No.	**Title**
301	How May Data on Chronic Disease Morbidity and Mortality be Collected and Analyzed in Order to Study Relationship of Occupational Environment to Chronic Disease?
302	Methods of Accelerating Predictive Tests of Toxicity and Carcinogenicity.
303	What is the Period of Retention of an Inhaled Air Pollutant in the Lungs, and How Does this Vary with the Physical and Chemical Nature of the Pollutants?
304	The Nature of the Cellular Changes Involved in the Pathogenesis of the Pneumoconioses.
305	Serum Enzyme Patterns in Industrial Toxicology.
306	What is the Anemia-Producing Agent of Benzene Exposure?
307	The Reactions of Man Following Definable Exposures to Toxic Compounds.
308	The Tissue Culture Approach to Toxicological Problems.
309	Development of Procedures for Preparing Aerosols of Desired Size Class.
310	The Physiological Responses from Chemical Stimulation of Bare Nerve Endings.
311	The Evaluation of Chronic Carbon Monoxide Poisoning as a Disease Entity.
312	What are the Limits of Man's Tolerance to Radiant Heat Sources?
313	Is the Inhalation of Oil Mist a Health Problem?
314	The Mechanisms of Pulmonary Response to Irritant Gases.
315	Epidemiological Considerations of Occupational Cancer.
316	Pattern for Occupational Health Services in Small Industries.

301. How May Data on Chronic Disease Morbidity and Mortality be Collected and Analyzed in Order to Study Relationship of Occupational Environment to Chronic Disease?

The Problem, Its Importance, Background and Setting: The role played by the occupational environment in the development of "non-occupational" chronic diseases is receiving increasing attention. This interest is in part due to hypotheses derived from clinical and laboratory observations on etiological factors related to the onset of these diseases; in part, it is stimulated by claims for financial compensation on behalf of employees who have acquired such diseases. In any event, the medical directors in a wide variety of industries, occupational health specialists and, in particular, those who are investigating the environmental factors which are involved in the causation of major chronic diseases feel the need to determine whether or not persons exposed to a certain work environment for a specified period of time develop a given disease more frequently than persons without such exposure.

What the Research is Hoped to Accomplish: The purpose of the research suggested here is to provide the means by which such determination more easily could be achieved. These means involve the development of:

- (a) routine mechanisms for the collection of facts regarding exposure to specified environmental conditions and duration of such exposure.
- (b) standards of comparisons.
- (c) appropriate methods of analysis of the data.

Approach: Present and Past Efforts: As is the case for public health in general, collection of data and analytic procedures for investigating the relationship of work environment to onset of disease are geared to the study of disease conditions for which the time lag between exposure to the environment and the onset of overt clinical signs of disease is brief. Thus, the medical or safety department can easily perceive an unusual concentration of acutely sick or injured persons from a single area of a plant. They can take steps immediately to validate the impression by counting the number of patients who work in the suspected area. They can also count all the persons who are exposed to the same environment and thus arrive at incidence rates. Furthermore, they can easily establish a standard of comparison by the appropriate selection of persons who were not exposed to the specific environment at the given time. Under these circumstances, the analytic technique is straight forward and relatively simple.

Unless the chronic disease is rare, as would be cancer of the paranasal sinuses, or the employees are a stable and highly skilled group, e.g., granite-cutters, working in a geographically limited area, a relationship between working environment and onset of the more common chronic diseases, cannot be easily perceived, even if it exists. Since the early symptoms and signs of these diseases are non-specific and gradual, the medical department may be by-passed to a large extent, the employee obtaining diagnosis and services from private practitioners or clinics. Even where the medical department is involved in the diagnosis, let us say of heart disease, a connection between the environmental exposure and the onset of the disease is not considered inasmuch as the individual may, and usually does, have a long history of many jobs, and it is not expected that his latest job will affect the onset of the disease. Generally, the final outcome is that the medical department loses contact with the individual when the latter leaves the plant because of disability.

Recognition of this problem has led to the utilization of information available through insurance records which provide data on the number of employees on whose behalf claims are made in specified calendar years. To arrive at a measure of mortality in relation to work exposure, it is necessary to know the number of persons exposed to the work environment for a given time period. Such knowledge as is available has to be obtained from records in the personnel office. The study on the relationship of lung cancer to work in the chromate industry illustrates the general approach. One aspect of that study was carried out by examining the mortality rates for several subsequent years among employees who were working in the chromate industry in a given year. In brief the approach is to identify individuals who were alive (and presumably not ill) at a certain point in time, i.e. establish a cohort, and to follow them for the number of years required by the natural history of the disease under study. For the identification of the cohort, records of the personnel department are employed; and in lieu of an actual follow-up, insurance records are used to identify those who died. Through the techniques employed in the construction of life tables, mortality and survivorship statistics are then computed. As a standard of comparison, statistics on mortality and survivorship for the general population are employed.

Approach: Potential Lines of Attack: Methodologic refinements are required in the above procedures in order to assess with greater precision the relationship between work environment and mortality (or disability). In the first place, the records of the personnel office do not always contain sufficient information regarding the past employment history of the individual, and, of course, will have no information on the work history of the individual after he leaves the particular work environment. On the basis of these considerations, Mancuso and Coulter have suggested the use of the work history information available through the records of the Old Age and Survivors Insurance program of the Social Security Administration. A systematic exploration of such records and of their potential contribution to the problem is one type of investigation required.

The analytic techniques employed in the life table approach require critical re-examination. The major issue is that individuals vary in their working pattern throughout life. Some persons are exposed intermittently, others constantly to a particular work environment. The exposure starts at different ages. Suppose that one person starts his exposure at 20 years of age, another at 40, and that both have 5 years exposure. Is this five-year exposure equivalent for the two individuals? When not, how are the data to be analyzed?

The use of the data from the general population with which to compare the mortality rates for a particular industry also raises some important logical issues. One of these is that we do not have adequate "generation" life tables and, therefore, must adopt the "current mortality" life tables. A second and more important issue reflects the fact that the general population contains first those who have not been able to enter the labor force because of physical deficiencies some of which increase the risk of mortality. Second, the general population contains persons who are unable to continue work because of physical conditions which also may increase the risk of mortality. Third, the general population will include persons who acquire a disability or higher risk of mortality from exposure to other etiological factors. Consequently, comparisons between mortality rates in employees exposed to certain work environment and the general population of workers may completely obscure the true relationship. Basic research is required, therefore, for the development of standards of comparison that are more appropriate for the study of mortality or disability in relation to the occupational environment, and which take into account the dynamics of work exposure and the selective factors which bring persons into and remove them from the labor force and from different occupations.

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302. Methods of Accelerating Predictive Tests of Toxicity and Carcinogenicity.

Problem: Recent amendments to the Food and Drug Laws have placed added burdens on the industrial toxicologist in the form of added time and animal numbers required for evidence of safety of products for human and animal consumption. Predictive tests of toxicity that may be performed in a short time and with fewer animals than are currently necessary are urgently needed.

Background: Currently, studies of 2 and up to 7 years duration may be required to provide evidence of safety of food additives and other industrial products. Often reproduction studies involving two or more generations may be indicated. In addition, administration of the agent at several levels, and a number of species at each level, are required. Shortening of these laborious and time-consuming tests is desirable to promote more rapid marketing of compounds used to upgrade and protect our food supply, as well as to reduce the ultimate cost to the consumer. The increased number of chemicals yearly would appear to prohibit normal development and proper safety evaluation of new products unless more rapid, sensitive, and less time-consuming approaches are developed.

Potential Lines of Attack:

1. The simultaneous performance of a one-year study on weanling

(45-day old) and yearling (365-day old) rats should be evaluated as a substitute for the currently required 2-year, lifetime feeding study. Consideration here should be given to the types of compounds best suited for this type of accelerated study, particularly in regard to accumulation of either the substance under test, or the effects of the substance on the body.

2. Similarly, in the area of carcinogenesis, comparable procedures might be applied in the painting of the skin and injection of rodents with potential carcinogenic agents to determine whether mice and rats treated for an additional year might give the same response as weanling animals treated over their entire life span.

3. Evaluation of metabolic accelerators should be made to determine whether accelerated metabolism would produce toxicity at an earlier period than would otherwise occur without, however, disturbing the ordinary mode of toxicity.

4. The application of biochemical profiles or patterns of response to altered metabolism as a result of the toxic agent should be explored. In this category, isoenzymes should be examined also.

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303. What is the Period of Retention of an Inhaled Air Pollutant in the Lungs, and How Does This Vary with the Physical and Chemical Nature of the Pollutant?

Problem: Atmospheric dusts cause pneumoconioses when inhaled over prolonged periods of time. In the development of the pneumoconiotic syndromes, contact of the pulmonary tissue with the pollutant plays a decisive role. The period of contact depends on the balance of the rates of deposition and elimination. Deposition is determined largely by concentration of the agent in the inhaled air. Elimination is accomplished by diffusion through blood or lymph, and by bronchial expulsion. Physical, chemical, immunological, and toxicological properties of the dust may accelerate, retard, or inhibit any one or more of these mechanisms, and thus the period of dust retention may depend on particle size and shape, water and/or lipid solubility, antigenic activity, behavior toward enzymes, and other factors related to the dust, as well as several factors related to the host.

Previous Work: Complete data are scarce, and a comprehensive study is needed. It has been more or less customary to regard dust retention as being governed by the "biological half-life" concept, a term borrowed from the laws of radioactive decay. If properly interpreted, that concept implies that always one-half of the amount of dust present is eliminated during a given time period, regardless of the size of the amount. Several studies indicate, however, that this is not so. Elimination curves obtained on certain metal oxides, as well as on certain organic compounds, start too steep, and continue too flat, for a true logarithmic curve. The pattern rather resembles a multi-phase system which is apparently governed by one factor in the beginning and by another factor later. Definition and elucidation of those factors, doubtless a problem of considerable merit in environmental pathophysiology, should be the substance of the proposed study.

Potential Lines of Attack: A comprehensive investigation would necessitate cooperation between several disciplines, especially chemistry, physiology, immunology, and pathology. Choice of the experimental animal is of some importance; it should be considered in consort with the test substances to be used. The latter may be selected on the basis of known pathologic, immunologic, and biochemical properties, and control animals would have to be treated with identical amounts of a substance reasonably similar to the test agent but with proven lack of activity in the investigated field. Familiarity with toxicology, pulmonary function, and ability to carry out quantitative assays of the agents - preferably by spectrophotometric, spectrographic, and/or x-ray diffraction methods - is a prerequisite for the successful completion of the study. Exposures may be accomplished by inhalation of the test substances in aerosol form, and for deposition-elimination equilibrium studies, this method is obligatory. For the establishment of elimination patterns alone, a single deposition of the test agents by intratracheal injection is satisfactory. Evaluation must be based on the chemical analysis of pulmonary tissue at defined intervals of time after deposition of the test agent. The study may be extended to the comparative evaluation of the pulmonary retention of a given substance in the free condition *vs* attached to an inert carrier by adsorptive, absorptive, or other forces. Since such combined pollutants are regularly encountered in field conditions, such extension would greatly enhance the significance of the investigation.

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304. The Nature of the Cellular Changes Involved in the Pathogenesis of the Pneumoconioses.

Problem: Recent advances in the structural and functional characterization of the living cell permit a better and more complete understanding of the pathogenesis of an ever-increasing number of diseases; metabolic and even some infectious conditions can now be described in terms of the damage done to cellular structures or functions. Cancer research is making great strides in this realm, and there is no reason to doubt that atmospheric dusts, too, exert their toxic activity on the cellular level. Successful investigation of these mechanisms would make a contribution of great value not only to environmental health but also to the entire field of medical science.

Previous Work: Study of cell structure commenced comparatively recently, and good reviews are available (1). Application of cytochemical principles helped decisively in the understanding of the pathogenesis of sickle-cell anemia (2), diabetes (3), phenylketonuria (4), and others. Among environmental diseases efforts were made to utilize cytochemistry in the understanding of silicosis (5) and beryl-liosis (6). More exhaustive and more fundamental studies are needed to elucidate these and other pneumoconioses more completely with respect to their pathogenetic features at the cellular level.

Potential Lines of Attack: Ideally, for a most complete study, an electron microscope should be available. However, valuable work can also be done by the use of chemical methods only. Experimental production of the desired syndrome in laboratory animals may be accomplished in dust chambers, and pulmonary tissue specimens obtained fresh at autopsy are to be processed in accordance with established biochemical procedures. By different centrifugation, the nuclear, mitochondrial, microsomal, and soluble supernatant fractions may be obtained from the tissue homogenate, and these fractions may be analytically characterized by a great variety of biochemical criteria. If an electron microscope is available, structural changes seen on electromicrographs of diseased tissue may be correlated with changes of composition or distribution as determined chemically.

Pulmonary tissue to be used for chemical analysis should be freed from blood by perfusion. Homogenization and centrifugal fractionation of pulmonary tissue has been described, and the selection of criteria by which the tissue specimens are to be characterized depends on the choice of the experimental animal as well as on the type of pneumoconiosis induced. Familarity with biochemical principles is needed for the prudent selection of these criteria. Inasmuch as the process of development of the disease may take several months or years, during which periodic assays of pulmonary tissue composition should be made, the problem usually cannot be answered by a short-term study, and the use of larger animal colonies is recommended.

Equipment Requirement: Some refrigerated working space, not necessarily a cold room, and a refrigerated high-speed centrifuge are essential. Electrophoresis equipment may be needed if changes in soluble proteins are to be used as criteria of differentiation. Other determinations usually do not require specialized equipment. Electron microscopic follow-up of the observed chemical changes would greatly enhance the significance of the study.

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305. Serum Enzyme Patterns in Industrial Toxicology.

The Problem: Too often the relationship between exposure to a given chemical environment and statistical evidence of increased morbidity or mortality becomes evident only in retrospect when the exposed individuals have become hospitalized. Under our expanding industrial system, the air we breathe, the water we drink, the food we eat, and the drugs we take into our bodies are subjecting us to thousands of new and old chemicals or foreign substances. Chronic exposure to traces of many toxic substances is a known serious health hazard, but chronic exposure to many new chemicals of unknown toxicity presents a vast new dimension of potential health hazards. When one considers that entire new industries are today based upon chemicals which were relatively unknown twenty years ago, that more than 50% of the products sold by the chemical industry today were not in commercial production twenty years ago, and that 90% of the drugs sold today were developed during the last ten years, the need for new methods of detecting metabolic alterations arizing from potentially toxic agents before clinical evidence of their effects is apparent becomes readily evident.

Background Information: R.J. Williams and his associates have compiled an extensive body of data to indicate that an exaggerated dependence upon the idea of normality may result in the loss of potentially important signposts of disease. Because an individual is well and "normal" does not mean that he or she is not a potentially ill person and that the roots of disease or early effects of a toxic agent may not be present in his makeup. The metabolic peculiarities of each individual instead of being categorized as within certain "normal" ranges should be considered as characteristics of the individual. This concept of biochemical individuality is illustrated by the wide ranges of many serum enzyme activities which have been observed among many "normal" healthy individuals.

If one accepts the concept of biochemical individuality, the question, then, is: How can this individuality best be determined? The morphologic and histologic description of a tissue has long been standard medical practice for the diagnosis of disease and the differentiation between "normal" and pathologic specimens. But the daily or weekly biopsy of liver, muscle, pancreas, or other organs is impractical. The method of choice is the examination of the serum. This has been termed "biochemical biopsy" by Wroblewski, who has stated his ideas as follows: "1. A tissue may be characterized by its enzymatic as well as its cellular composition. 2. Morphologic reflections of tissue reactions to degerative, infectious, and neoplastic disease states may have their counterpart in enzymatic alterations in and about the tissue involved. 3. The enzymatic tissue changes may find reflection in comparable enzyme changes in the body fluids which traverse and/or bathe the tissues. 4. Correlation of clinical facts with quantitative and serial enzyme changes of body fluids contribute to the differential diagnosis of disease states."

In an attempt to test the hypothesis of biochemical individuality, Frajola *et al*, have determined several serum enzyme activities (phosphohexase, isonerase, glutamic-oxalacetic transaminase, glutamic-pyruvic transaminase, lactic dehydrogenase, amlic dehydrogenase, alkaline phosphatase, leucyl aminopeptidase, aldolase and acetylcholinesterase) of sera from several pairs of identical twins, sera of siblings and parents of the twins, and sera of other unrelated healthy individuals. Remarkably specific serum enzyme patterns were obtained. Likewise sera of a variety of patients exposed to a variety of toxic agents have been examined. The serum enzyme patterns so obtained differed greatly from the patterns of the healthy individuals. It appears that serum enzyme patterns in disease no longer reflect the characteristic metabolism of the individual but reflect the metabolic aberrations arizing from the disease.

Potential Lines of Attack: The measurement of as many biochemical parameters as possible on a given serum sample is indicated. The more parameters that are available the more specific the characterization should be. Serum enzyme measurements are suggested because of the high degree of sensitivity obtained owing to the catalytic activity which is measured rather than the actual concentration of the substance itself. Serial measurements (sera assayed at time intervals of from two weeks to several months) would aid in establishing a trend or an effect of chronic exposure to a potential health hazard.

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306. What is the Anemia-Producing Agent of Benzene Exposure?

Problem: Progressive, fatal anemia is the characteristic response in man following low-grade exposure to benzene. No other monocyclic hydrocarbon is known to produce anemia. It is also known that the metabolism of benzene differs from its aliphatic derivatives, (1,2). It is important to know the anemiogenic factor of benzene because then measures may be devised to prevent the development of this toxic anemia following exposure.

Background: Six metabolites of benzene, in addition to carbon dioxide, have thus far been identified following exposures to benzene (3). They are phenol, catechol, quinol and hydroxyquinol, as their conjugated products, trans-trans-muconic acid, and 1-phenyl mercapturic acid. With the exception of carbon dioxide, all metabolites are chiefly found in the urine. Little attention has been given to the search for benzene metabolites in tissues, particularly bone marrow.

Potential Lines of Attack: More precise balance studies using C^{14}-labeled benzene might reveal as yet undisclosed metabolites of benzene, which upon readministration, either alone, or in combination, might lead to the production of the characteristic anemia.

Possibly a more fruitful line of attack might be a search for C^{14} metabolites of benzene in the bone marrow. Readministration of the metabolite should result in marrow changes characteristic of benzene myelotosicity to confirm the identity of the anemia-producing agent.

Requirements: Familiarity with radiotracer and chromatographic techniques, along with histologic competence to evaluate bone marrow changes.

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307. The Reactions of Man Following Definable Exposures to Toxic Compounds.

The Problem: Many toxic materials can be found now, and more are added constantly to man's environment in his occupation, home, and community. Simple and sensitive tests for the early detection and follow-up of human reactions to exposures of various degrees are urgently needed.

Background Information: For many years it has been generally accepted that species-homologous tissue components are not antigenic. Nevertheless, auto-immune mechanisms have long been suspected and even accused of playing an important role, particularly in the so-called collagen group of degenerative diseases. A sizable number of observations in this area have been reported recently, especially during the last decade. Some of this resurgence of interest in the relatively old concept that serum antibodies are not always beneficient but can be responsible for serious progressive disease, stems from the very recent development of much more sensitive tests for the demonstration of an immunological response. Quite a few investigators have suggested that many important diseases may be related to, or explained by, the formation and subsequent harmful activity of auto-antibodies. Further, evidence has been brought forward that these substances may be produced experimentally and by exposures with certain drugs and chemical compounds.

The tissue components apparently become antigents at the time of cell death *in vivo* or by subsequent combination with a noxious toxin or chemical. There is an alternative interpretation to be considered in that this may be solely an adventitious reactivity of serum globulins and the so-called auto-antibodies demonstrated are not formed because of a specific stimulus. It must be recognized that they seem to possess many of the properties of a typical antibody. On the other hand, no strict organ specificity has been noted other than with very specialized tissues, such as the lens of the eye and spermatozoa. More recently, the immunologic approach to Hashimoto's disease has stimulated much additional research in this field.

Potential Research: One possible approach to this problem would be the employment of serological and immunological techniques. This would involve study of both humoral and cellular responses. The former might be indicated by the development and persistence of antibodies, both specific and non-specific. The latter might be signalled by the development of different cell types and intracellular components.

Facilities Required: An investigation of the immunological response and cellular changes will demand:

1. The capability for critical comparisons and later, selection of the most sensitive serological techniques;
2. The means to separate and describe serum fractions by electrophoresis;
3. Equipment for the fluorescent antibody techniques; and
4. An electron microscope for cell studies.

Procedure: The first step would be to develop the necessary facilities and skills and then move into experimental and field investigations, employing the tests as epidemiological tools.

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308. The Tissue Culture Approach to Toxicological Problems.

Problem: Any toxic agent may affect a given vital organ or body system at the level of the organism and lead to injury or death. The toxic effect must ultimately be interpreted in terms applicable at the cellular level. Question arises, however, as to how direct or indirect the toxic action is with respect to the cellular units? Does the toxic agent exert its effect directly on the cell by actual intimate contact with the cell? Or, does it act indirectly by reacting with body fluids or other extracellular products which in turn might exert an effect on the cell? Does the toxic agent affect all cells of the organism in a similar manner or are certain types of cells much more sensitive than others? These and many other questions relating to the mechanism of action of toxic agents in the organism may well be answered by systematic inter-disciplinary studies of the effects of toxic agents on cells cultivated *in vitro.*

Approach: Past and Present Efforts: During the early years of development of tissue-culture techniques, many isolated observations were made on the effects of toxic agents on cells. However, because the techniques at this time were not very well refined, interpretation of results was often difficult. We now have the advantage of the great strides made in the field of tissue culture over the past 10-12 years such as simplification of procedures, establishment of strains and clones of cells suitable for long-term experimentation, development of cell suspension culture techniques, development of chemically defined media, development of quantitative methods for the determination of cell growth, improvement in time-lapse photomicrographic methods, etc.--all of which have paved the way for more critical investigations using tissue cells cultivated *in vitro*.

Pomerat (4), Biesele (1), Pomerat and Leake (5), Verne (7), and others have employed tissue cultures of primary explants for short-term toxicological studies. Rose (6) has developed a perfusion chamber which has been quite useful for time-lapse photomicrographic studies of the effect of chemical agents on cells. Pace (2) has developed a relatively simple tissue-culture system using a modified T-60 flask which permits direct exposure of gaseous toxicants to a monolayer of tissue cells. The effects of the toxic agents on the morphology of the cells have been studied by visual microscopic observations and time-lapse photomicrography. Effects on cell proliferation have also been determined by cell enumeration methods (e.g., Pace and Elliott (3)).

The above studies have shown evidence of (a) differential sensitivity of various types of cells to toxic agents; (b) specific morphological effects at the nuclear level, or cytoplasmic level, or both, which may be useful criteria for specific mechanisms of action; (c) differential inhibition of cell proliferation by sub-lethal doses of toxic agents; and (d) acquisition of tolerance by some cells to toxic agents.

Approach: Possible Future Efforts: The following suggestions are made as possible means toward gaining further insight into the fundamental mechanisms involved in the action of toxic agents on cells. First, the development and refinement of standardized toxicity tests should be considered. In this area viability tests based upon the use of vital dyes or upon the plating technique might be useful. Secondly, much more descriptive information should be accumulated (in a systematic way) regarding the various changes brought about in the morphology of the cell by toxic agents. Since structure and function are so intimately linked together, such information should give some clues regarding common mechanisms of toxic action. It would amount to clinical diagnosis at the cellular level. This objective could be achieved through time-lapse photomicrographic studies integrated with electron microscopic studies. Third, a great deal of emphasis should be placed on biochemical studies run in parallel with the above-mentioned morphological studies. It would be of considerable interest, for instance, if any of the characteristic morphological changes could be consistently correlated with changes in respiration, effects on the cytochrome system, RNA synthesis, etc.

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309. Development of Procedures for Preparing Aerosols of Desired Size Class.

Problem: A number of research problems in occupational health, toxicology, and air pollution depend on the availability of efficient procedures for securing aerosols of uniform size. This need arises from the fact that the locus of deposition, and consequently the mode and intensity of toxic effect of inhaled aerosols, is generally dependent in some degree on their particle size. As examples of this size dependency, one may cite pneumoconiosis-producing dusts such as silica and beryllium which are only effective to the extent that they reach the deeper portions of the lungs; thus small particles are particularly active. Conversely, lung cancer may arise predominantly from the larger particles which are preferentially trapped in the conducting airways in the upper part of the lungs. Similarly, physical, as well as biological, studies in these fields often require a means of securing aerosols sorted into size classes.

Background Information: A very efficient procedure for the production of uniformly sized aerosols is available in the Le Mer-Sinclair generator. Its applicability is, however, limited to materials having very restricted physical characteristics. The procedures now used for sorting aerosols depend largely on classification by centrifugation, sedimentation, or elutriation. These procedures are inefficient and, where intermediate storage before use is required, agglomeration often occurs with consequent change in effective particle diameter. These procedures, in addition to other disadvantages, often involve the loss of material and the handling of relatively large quantities of dusts in order to secure an adequate supply of the size class desired. This is a major handicap when dealing with materials available in limited supply or with substances which are highly hazardous such as potent carcinogens or radioactive materials.

Potential Line of Attack: A particle classifier capable of direct delivery of the sought size range would have widespread research application. Ideally such a unit would be adaptable to a wide variety of aerosols, compact, easily enclosed, have high efficiency, and be capable of continuous direct delivery to the experimental system for which the aerosol is intended. Since the ultimate objective is generally related to the biological action of the aerosols, a sorting procedure dependent on aerodynamic properties of the particles is likely to be preferred since these properties predominate in determining the locus of deposition in the lungs. The available systems which have had limited success for specified purposes include the spinning top, conifuge, cascade impactor, air elutriator, and others. All of these in the present form have substantial limitations and the development of new, or the improvement of existing, devioes would be of decided benefit. These studies could be handled by an engineer or physicist experienced in aerosol technology. No definite estimate of time requirement can be made but an initial project of two to three years would be in order.

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310. The Physiological Responses from Chemical Stimulation of Bare Nerve Endings.

Problem: The chemical excitation of bare nerve endings plays a large role in the initiation of numerous irritations and pains suffered by man. The nerve endings in the cornea and the mucous membrane lining the nose are of immediate concern for people in the occupational environment and those living in areas of smog. How are these nerve endings stimulated by chemicals and what tissue characteristics are responsible for the chemical specificity? Many irritants excite the endings in the cornea but not the nose, and vice versa. Is it possible to find a molecular basis for inhibition of chemical excitation?

The importance of the bare nerve endings in production of pain by burns and other sources cannot be overrated. The pain arising from the application of foreign chemicals to an abrased area of tissue is well known. What makes these endings so sensitive under such conditions? What influence does the excitement of these nerves have on other functions of the body by way of reflexes? Although such considerations are of major importance to the comfort of man, surprisingly little research on these basic problems has been performed in recent times.

Background Information: The physiological bases for visual and auditory sensations have been thoroughly studied with the most modern methods. To a lesser degree, the chemical senses of gustation and olfaction have also been investigated with a fair amount of success. Too little research has been performed on the bare nerve endings and in particular their chemical excitation. Many of these nerves are C-fibers, the smallest in size found in the body. Their small diameter increses the difficulty in using an electrophysiological approach to their study. Since no special end organs are associated with them, the nerve fibers have been little studied anatomically. The regeneration of destroyed nerve endings has been studied to some extent, but has not been correlated sufficiently with the return of sensation to that area.

Potential Lines of Attack: The most impressive method of studying sensory endings has been the recording of the electrical activity associated with the sensory nerves. The magnitude of neural activity may be recorded electronically and used as a measure of magnitude of response to chemical stimulation of the nerve ending. These methods, which have been so useful in the study of the major senses, should also be utilized in the study of the chemical excitation of bare nerve endings. The recent development of gas chromatography allows the experimenter to identify irritating or painful stimuli which may exist in a gaseous form. This is particularly useful in the study of chemical excitation of the cornea and of the mucous linings of the nose. Bare nerve endings of the trigeminal nerve in the nose have been studied by recording their neural activity stimultaneously with that developed by the nearby olfactory organs. Such studies allow the experimenter to compare the specificity of chemical excitation of the two sensory systems. Similar methods may be applied to the nerve innervating the cornea as various gaseous irritants or chemicals in aqueous medium are flowed over the surface of the eye in experimental animals. Preliminary work in this field indicates that such excitation results in destruction of the endings, which presumably regenerate in a very short time.

The study of painful stimuli to other areas of the body may be facilitated by the production of artificial blisters to which suitable chemical media may be applied to the uncovered endings. Suitable behavioral methods should be devised to study the behavioral responses to chemical irritations and pain, which may then be correlated to the information obtained by recording from the peripheral nerve fibers.

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311. The Evaluation of Chronic Carbon Monoxide Poisoning as a Disease Entity

The Problem: Carbon monoxide constitutes a universal public-health problem. It is still a controversial issue whether continuous or often-repeated exposure to low concentrations of carbon monoxide that do not produce acute symptoms and signs leads to eventual disease. This type of carbon monoxide poisoning has been produced in animal experiments, with concentrations of 20 per cent carbon monoxide hemoglobin, i.e., the upper limit of the generally accepted normal level (1). Its occurrence in man has not been accepted by most American authors. It is true that many reports to the contrary refer to repeated acute poisoning. A number of cases, however, are at least suggestive of true chronic carbon-monoxide poisoning.

Background of Information: Only very recently, Breysse (2), summarizing the results of a survey, stated that in all probability the recommended threshold limit value of 100 ppm for carbon monoxide is too high. The foreign literature on the subject is far more affirmative, although a large part of it, too, deals with repeated acute poisoning. At the thirteenth International Congress on Occupational Health (1960), Crisan et al (3) reported a study on 330 workers exposed to low concentrations of carbon monoxide and described the syndrome of chronic carbon monoxide poisoning. Also, these authors suggest a revision of the existing threshold limit value.

The clinical diagnosis of chronic carbon-monoxide poisoning in man is made difficult by the fact that only vague and uncertain general complaints are the rule. The results of more refined examinations, e.g., otoneurologic studies and investigations of the visual function, appear to support its occurrence.

The study of behavior (higher nervous activity) that has been developed and used more recently in Russia, Czechoslovakia, and Switzerland may provide a deeper insight into clinical effects of low concentrations of carbon monoxide. These newer studies attempt to assess the integration of an organism to its external environment, whereas the more classical studies of pathology and histology are more concerned with the integration of the organism's internal environment (4).

One or two typical examples of such studies may be pointed out. One of the simplest forms of behavior that can be studied in experimental animals is activity. Boche (5) has shown that locomotor activity of rats can be measured by counting the daily revolutions of a running wheel, and that this form of activity is significantly depressed when the animals are exposed to smog. The results of work done by Brieger and LaBelle indicate that locomotor activity of this type is not distributed at random in time but conforms to a pattern which can be analyzed by means of the information theory of Shannon. The information content of the activity pattern, which is a numerical measure of the extent to which any observed pattern differs from a random distribution, proves to be an even more sensitive criterion of exposure to smog than the total activity.

Grandjean (6) has studied the effect of low concentrations of a halogenated hydrocarbon on conditioned reflexes in the rat. He has shown that exposure to low concentrations of trichloroethylene, heretofore believed to be without effect on animals, caused demonstrable changes in the performance of a conditioned reflex in the rat. Grandjean and others have worked mostly with reflexes involving a reward in the form of food or water, but the literature of experimental psychology contains many tests of this nature which could be adapted to the specialized needs of toxicologic investigation.

Potential Lines of Attack: The suggested approach to the problem of chronic carbon monoxide poisoning might be somewhat as follows. A battery of tests along the lines suggested above should be selected and developed into routine procedures. On the basis of this preliminary work the required numbers of sets of replicate equipment should be installed in duplicate chambers, of which the one contains purified air, and the other a concentration of carbon monoxide sufficient to produce low but measurable carbon monoxide hemoglobin levels in the blood of the test animals. The two chambers should be operated until demonstrable changes have occurred in the exposed group.

Similar studies may be made on human subjects.

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312. What Are the Limits of Man's Tolerance to Radiant Heat Sources:

The Problem: Studies of the physiological effects of work in high ambient temperatures, nude and in a variety of types of clothing have been made. The results insofar as they deal with dry-bulb temperatures up to 120° F. and wet-bulb temperatures up to 96° F., are in such detail and in such good agreement as to provide practical solutions to these problems. (1)

The problem which has not received adequate study is the effects of high radiant temperatures with or without high ambient temperatures in various varieties of clothing. Belding and Hatch (2) have tried to solve this problem from a study of the environment alone but without success. Two examples will clarify the problem:

1. Pot crackers in aluminum reduction plants work briefly but hard in front of furnaces whose face temperatures at the work area

may run to 200°F. The air temperatures may be from 70° F to 120° F. with humidities at or below 60%. Heat collapse with or without a temperature elevation is common. These men fatigue very rapidly. Their pulse rates climb to high levels. They sweat moderately to profusely and develop some fever in a few minutes. Careful heat balance studies and safe physiological exposures have not been ascertained.

2. Man will shortly go into space. On re-entry into the atmosphere from a period of from 5 - 30 minutes he may be exposed to wall temperatures of 450° F. and air temperatures of 250° F. How and to what degree need he be protected, especially if living at one-half on atmosphere pressure in a suit pressurized by air whose humidity has reached 100%?

This problem is also encountered in glass factories, steel mills, rubber factories, oil well fires, very deep mines, and refractories ovens.

Potential Lines of Attack: Research in this area may very reasonably hope to define man's limits of tolerance to exposures to radiant heat sources, and to describe the principles involved in protecting him beyond these limits. The protective limits of various types of clothing and shielding will be an easy by-product. The basic physical-physiological problem of the extent to which the human body is a "black body" will be elucidated.

Exposure of thoroughly acclimatized human volunteer subjects in a chamber where air temperature may be controlled within 1°F. between 70°F. and 250°F., relative humidity controllable within 1% in the range 4 - 95%, and wall temperatures controllable within 1 - 10°F. in the range 70° - 450°F. with complete control of air movement. Sweat loss, body thermal equilibrium, cardiorespiratory response, corticosteroid response, and mental reactions should be systematically studied in a wide variety of parameters covering all known industrial exposures and the anticipated space-ship exposure.

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313. Is the Inhalation of Oil Mist a Health Problem?

Problem: In industry and agriculture there is a considerable worker population exposed to inhalation of oil mists. Although concern over these exposures has existed for several years, little has been done to define the real significance of this potential hazard. There is increasing concern over this occupational health problem on the part of labor, industry, and official health agencies. This concern stems mainly from (a) previously recorded cases of oil pneumonia from use of mineral oil and oil-containing sprays or nose drops, (b) the increasing population subject to exposure, and (c) the occurrence of skin cancers associated with cutting oils.

Background of Information: While there is a substantial number of workers in many occupations exposed to oil-mist inhalation, definitive information on health implications is either lacking or generally negative. For example, in view of the population exposed, there is a striking lack of reported cases of illness related to inhalation of oils. There is also a paucity of information on the physiological response to the inhalation of oil particles in concentrations experienced in work places. Of special importance is the occurrence of skin cancers associated with the use of cutting oils. Many occupational exposures to oil mist result from the use of these oils. The obvious question is raised as to a possible lung cancer hazard.

Since the first case of oil pneumonia was reported in 1925 (1) there have been well over a hundred recorded cases. They have come from taking oil by mouth or the use of oil-containing nose drops or sprays. The pathology of oil pneumonia has been described by Sundberg (2) and others, but information on occurrence of occupational oil pneumonia is lacking. Some experimental work has been done by LaBelle (3), Lushbaugh (4), Shoshkes, and more recently by Stokinger.

Possible Lines of Attack: Several basic questions need to be answered by properly designed research. Can any effect of oil-mist inhalation be measured in an exposed population? The answer here lies in an epidemiological-statistical study, coupled with clinical observations. This study should be directed toward any lung involvement with emphasis on oil pneumonia and lung cancer. Environmental data would be most valuable for correlation purposes.

Of equal importance is the need for long-range animal studies, coordinated with the above described work, to determine response at various exposure levels and to study further the mechanism in the handling of oil particles by the lung. The work recently started by Stokinger could serve as a foundation for expanded work, since it is occupationally oriented by design. The real concern in many areas is the aspect of a lung cancer hazard. In long-range animal studies, this aspect should be covered.

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314. The Mechanisms of Pulmonary Response to Irritant Gases.

The Problem: Numerous gases encountered in industry (and elsewhere) have the property of initiating a series of physiopathologic changes in the lungs, including asthma, atelectasis, and pulmonary edema. Extensive research has been done on the pathologic changes observed *post mortem*, but there is a significant lack of information about mechanisms, which need to be understood as the theoretical basis of prevention or therapy.

Background of Information: Much of the information on physiologic responses was obtained for war gases at a time when methods for pulmonary function measurement were not highly developed. Among such methods are the improved techniques for measuring pulmonary diffusion capacity for respiratory gases, ventilation and perfusion distribution ratios, and mechanical properties of the lungs and airway. The last-named measurement has been proven to be an extremely sensitive indicator of pulmonary reaction to inhaled gases, in that resistance to air flow may be increased as in asthma, when concentrations are breathed that are much too low to produce a pathologic effect. However, the mechanisms of these effects are poorly understood or unknown.

Sulfur dioxide is a gas which occurs in a number of industrial processes, such as paper manufacture, electrolysis, etc., and which has been the subject of recent physiologic experimentation. Industrial workers are said to become insensitive to concentrations of the gas which are quite irritating to those previously unexposed. On the other hand, two investigators in Britain have reported that they became hypersensitive on repeated respiratory exposures to sulfur dioxide. Alterations of endogenous protein by the gas to form an antigen can be postulated to explain a developed hypersensitivity, but there is no evidence from industrial experience to suggest that hypersensitivity has developed in exposed workers.

Normal persons who have not previously been exposed to SO_2 react with an increase of airway resistance to concentrations as low as 5 ppm. Respiratory infections or a history of allergy may be associated with exceptionally strong responses. After several minutes of exposure, the measured effect becomes essentially constant and the symptoms are ameliorated.

Possible Areas of Research: Epidemiologic investigation might show whether the incidence of non-specific pulmonary disease is increased in workers exposed to excessive SO_2. One source of bias would be the possibility that such workers might be "selected" on the basis of their "non-reaction" or good adaptation to SO_2 exposure.

Pharmacologic and physiologic research might reveal the receptor areas that trigger the asthmatic response and elucidate the role of histamine and of the autonomic nervous system in the production of bronchospasm and excess fluid in the air passages or tissues.

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315. Epidemiological Considerations of Occupational Cancer

Problem: Thousands of industrial chemicals have been used in industry for many years whose long-term toxicological effects on the working population have not been determined or explored. Little toxicological information is available from low exposures over prolonged periods of time. Some of these industrial chemicals are known to be carcinogenic in humans and others in animals. The marked excess of cancer for males to that of females in urban areas for certain sites warrants the consideration of the working environment as a potential source for occupational cancer. The changes in employment and the latent period for the development of cancer pose difficult epidemiological problems.

Background Information: Epidemiological considerations may be focused on specific chemicals, determining the population at risk wherever a chemical exists in the working environment, or focused on specific cancer sites which have shown a marked excess among the males in urban areas, or where other studies have provided some epidemiological lead referrable to the occupational environment. Five such examples are included which represent individual areas of research that warrant more extensive epidemiological studies and serve only to illustrate the potential opportunities for epidemiological research which exist because of the many other chemicals in the industrial environment.

Excess lung cancer has been found in workers engaged in the manufacture of chromates (1) and animal experimentation has produced malignancies in significant numbers following exposure to six different chromium compounds (2). Chromium is now suspect as a carcinogenic agent and is used in a large number of industries.

Acute pneumonitis and chronic berylliosis have occurred in workers exposed to beryllium compounds and processes. This reaction has occurred notably in the beryllium-producing industries and the fluorescent-tube industries where beryllium phosphors had been used. Vorwald's experimentation (3), which resulted in the consistent production of lung cancer in rats, has raised the question of whether cancer will develop in those workers who had been exposed to beryllium in the working environment a number of years ago. Although the number of workers who have been exposed to beryllium has been limited, the use of beryllium is increasing rapidly and the need exists to determine whether there will be a human counterpart to the results obtained in Vorwald's animal experiments.

Benzpyrene is a known carcinogen to experimental animals and is suspected of being carcinogenic to man. Although major emphasis has been attached to benzpyrene as a component of air pollution, occupational exposures do exist and have occurred in related industries and represent an epidemiological lead worthy of pursuit.

A number of attempts have been made to explore the relationship of asbestos and lung cancer. Most of these investigations represent autopsy findings. However Doll's (4) work has provided statistical evidence from a population for workers exposed to asbestos. Recently Braun and Truan (5), however, in an epidemiological study of asbestos miners reported negative findings, although some limitations are apparent in this study. A more thorough investigation is required.

Tumors of the central nervous system among deceased male residents of Ohio have been found to show an increased gradient in mortality rate from rural to urban areas; an excess in rates for males over females in the metropolitan areas; and an excess among the deceased who were employed in the manufacturing industries over those in agriculture. In addition certain industries within the manufacturing group show a much higher rate than others. This combination of data suggests that the working environment be studied as leads to environmental or chemical causes for tumors of the central nervous system (6).

Possible Lines of Attack: There are inherent problems associated with the conduct of epidemiological studies of industry particularly as they relate to long-term effects such as cancer. In addition to the limitations of availability of personnel records in a given industry, employment of a worker may occur in a number of different industries over a 20-30 year span; the types of processes and related exposures may vary between individual industries and within the same industry over a period of time; the population at risk may be at a single area or the contamination may occur throughout the entire plant; the latent period and its relation to duration of exposure and concentrations of chemicals are undetermined; and the lack of comparative industrial control populations.

Possible lines of attack relate to the establishment of cohort populations in specified years, for example 1932-1942, of workers who were employed in the specific industry where the occupational exposures occurred. Through the use of Social Security employment records this population can be traced through the records of the Bureau of Old-Age and Survivors Insurance to determine those who died by 1960 or later, and finally the specific causes of death (7). Cohorts of individual plants can be selected from the same type of industry who had different types of processes and related exposures as well as general exposures throughout the plant of the chemical occupational exposure. Similarly, biostatistical research could be conducted in the development of a cohort control from a national sampling of the industrial population covered by Social Security as well as the analytical treatment and development of a control referrable to multiple employment and duration of employment.

Another approach would relate to identifying from company insurance and union records the individuals who were exposed in specific departments or areas of a plant to the chemicals or processes under suspicion. This information, with the corresponding social security number, could be used as a cohort for processing through the Social Security Administration a request to obtain data related to the actual population who were at risk in any given year from 1937 on.

A third approach would relate to the establishment of national registries of exposed populations at risk through inter-industry cooperation as well as international unions in which controlled air monitoring had been established, and to arrange for the long-term observations of the cohorts through medical departments, insurance companies and union records and family contacts.

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316. Pattern for Occupational Health Services in Small Industries.

The Problem: At the present time a well-established pattern of good practice is available as a guide for providing industrial hygiene and medical services to large industries. No such pattern is available for small industries. In relatively few instances have successful systems been devised to meet these needs. In fact, there is not available at this time a concise evaluation of the need of such services to small industries.

Background Information: In a general sense, the need for such services is widely recognized and has been noted many times. It is stated that over 99% of the establishments under Social Security employ less than 500 workers, and, further, it is estimated that two-thirds of the entire labor force is employed in small business establishments. In some instances industrial clinics limited primarily to traumatic surgery are accessible to small units and also in some cases the industrial hygiene services of the local governmental unit may be available to a limited extent. Particularly lacking are industrial-hygiene services for the routine control and monitoring of working environments.

There are a number of reasons for the meager availability of such services: 1) the units in question are diverse and sometimes scattered; 2) no one unit is capable of supporting the proposed services independently; 3) doubt has been raised as to whether the anticipated return justifies the outlay; 4) in some instances the medical profession has not encouraged such systems on the mistaken assumption that this action would infringe on the usual practice of medicine; 5) the failure to define in a concise and objective manner the need and the expected return.

Possible Lines of Attack: It seems possible that a well-planned study aimed at the following four objectives might provide the basis and impetus for developing such services: 1) definition of need; 2) estimate of anticipated benefits; 3) outline of mechanisms for establishing services to small industries; and 4) costs.

It is conceivable of course that such systems are impractical; in any case objective evaluation is required. The suggested study is not research in the sense used in the basic sciences; but it is, however, an urgent inquiry and one that in order to be well done will require the skilled application of a variety of procedures, particularly those used in epidemiological and statistical research. The studies should be done in a metropolitan area of substantial size and should undertake to determine the distribution of businesses by type and number of employees. From this sample, selected industries would be examined in more detail to determine the kind and extent of occupational health service available (including nursing, medical, and industrial hygiene), illness and absentee records, the current insurance costs and claims figures, etc. These data would be contrasted with the experience of larger industries as nearly comparable as possible in the kind of labor force but with occupational health services. Also it would be desirable to secure views from management, labor, and the medical profession as to acceptable procedures for the provision of cooperative services. Particular attention should be given to the availability of routine industrial hygiene services for environmental control in small business with potentially hazardous exposures. Two years should permit completion of such a study and preparation of a report which should incorporate suggested plans for model units.

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SECTION IV. WATER SUPPLY AND WATER POLLUTION

Problem No.	Title
401	Enteric Bacteria in Canning Plant Wastes.
402	Protection of Aquatic Life From Toxic Wastes.
403	Organic Contaminants Affecting Water Quality.
404	Sludge Dewatering With Synthetic Polymer Coagulants.
405	What Are the Biologically Resistant Organic Compounds in Digested Sewage Sludge?
406	The Behavior and Persistence of Enteric Viruses in Sewage Polluted Water.
407	The Utilization or Disposal of Biological Solids Produced in the Bio-Oxidation of Industrial Wastes.
408	What is the Quantitative Effect of Algae and Other Aquatic Plants on Dissolved Oxygen Resources in a Stream Receiving Organic Pollution?
409	The Effect of Adsorption By Particulates on Bacterial Pollution and Its Relation to the Sampling, Analysis, and Interpretation of Pollutional Data.
410	The Effect of Siltation and Turbidity on the Self-Purification Processes of Streams.
411	What Specific Types of Organics Escape Conventional Complete Sewage Treatment Processes and What Are Their Characteristics?
412	Comprehensive Study of Organic Pollution Die-away and the Influence of Temperature, Flows, Etc., in Waterways.
413	Thickening and Dewatering of Sludges Produced From Clarification of Industrial Effluents.
414	Bacterial Flora of Polluted Waters.
415	Instrumentation For Continuous Monitoring of Polluted Streams.
416	Adsorption, Desorption, and Ion-Exchange in Ground Water Flow.

417 The Sanitary Significance of the So-Called "Aftergrowth" of Coliform Organisms in Waters Receiving Treated Sewage Effluents.

418 The Effect Upon the Domestic Consumer of Trace Chemical Elements and Compounds in Water Supplies.

419 The Biochemical Degradation of Sulfonated Lignins.

420 The Rate of Reaction Between Dissolved Oxygen and Reduced Sulfur Compounds.

421 The Effects of Photosynthetic Plankton Upon the Pollutional Loading Capacities of Surface Waters.

422 Characterization of Taste and Odors in Public Water Supplies.

423 Identification of Compounds Causing Taste and Odors in Mountain Streams.

424 Septic Tank Seepage Fields As Sources of Algal Nutrients.

425 Permissible Plant Nutrient Levels in Streams.

426 Requirements for Protection of Water Reservoirs From Sub-Surface Sewage Disposal Systems.

427 Mechanism of Hydrogen Utilization in Depolarization of Corrosion Cells by *Desulfovibrio desulfuricans.*

428 Decontamination Efficiency of Water Treatment Plants for Various Radioisotopes.

429 Improvement of Membrane Filter Method of Evaluating Numbers of Coliform Organisms.

430 Effects of Controlled Recreation on Terminal Reservoirs.

431 Screening of Potential Water Works Chemicals for Toxicity, Taste and Odors, or Other Esthetic Aspects.

432 The Solubility of Magnesium Hydroxide.

433 Tertiary Treatment of Waste Waters.

401. Enteric Bacteria in Canning Plant Wastes.

The Problem: In the processing of many vegetables and fruits prior to canning, the waste waters may be expected to contain high concentrations of coliform bacteria. Most of these organisms are *Aerobacter* or intermediate forms originating in the soil from which the crops are taken. In many instances, however, enteric bacteria of human origin may be present as a result of fecal contamination of the soil or the human handling of the produce prior to washing. There is a need to evaluate the extent of such contamination, the survival of enteric bacteria in the waste waters, and the dangers of recontamination of crops that are irrigated with these waters. There is also a need for information about the residual contamination on produce that is eaten raw.

Background Information: In many agricultural areas, the personal sanitary habits of itinerant workers leave much to be desired. Despite the educational efforts of local and state health agencies, crops have been known to be contaminated from soil that has received human excrement or from picking and packing with unclean hands. Two problems arise from these potential sources of contamination. First, there may be a residual coliform content on washed produce that is packaged fresh for consumption without cooking, e.g. tomatoes, strawberries, lettuce, celery. Second, the wash waters may be discharged to a stream that is used for water supply or bathing, or they may be returned to the soil through sprinkler irrigation of edible crops. In this latter manner, enteric organisms that were not a problem on their original crop (which must be cooked) may become a health hazard through the recycling operation.

Previous Work: Normally, cannery wastes are not assayed for bacteria or other organisms, although some investigators have measured the total count of these waters. Seldon, if ever, have coliform organisms been evaluated and apparently no one has differentiated the *E. coli* or enterococci in such wastes. Dunlap and his colleagues in Denver have made extensive studies of the occurrence and survival of pathogenic bacteria in irrigation waters and on irrigated crops, but these investigations do not relate to cannery wastes. Similarly, Norman and Kabler have evaluated bacteria in irrigation waters and on the washings of crops. Rudolfs *et al* have prepared a comprehensive review of all information available up to 1951.

Possible Avenues of Approach: Until more is known about the extent and nature of this problem, it might be well to conduct surveys of typical produce-processing plants to evaluate the occurrence and concentration of coliforms, *E. coli* specifically, and enterococci in wash waters. This survey might be accomplished through a cooperative venture to enlist the services of cannery laboratories in many different geographical areas and for several fruits and vegetables.

Another approach might be to concentrate the effort at one or two locations where a variety of crops are processed and where heavy contamination with enteric organisms is suspected. At such a location, the survival of these organisms during the washing operations and disposal procedures could be evaluated.

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402. Protection of Aquatic Life from Toxic Wastes

Problem: Toxic materials from many sources enter surface waters and destroy valuable aquatic resources. In many instances valuable sport or commercial fisheries or shell fisheries have been destroyed or seriously depleted. Major expansion in the manufacture and use of new products such as synthetic fibers, plastics, pesticides, detergents, and rocket propellants will increase this problem even more in the future.

Objectives: To develop methodology and information to evaluate correctly the toxicity of wastes or other contaminants entering surface waters.

Present and Past Efforts: Reasonably good laboratory bioassay methods have been developed for measuring the acute toxicity of chemicals and wastes to fish. The results are usually expressed as the 24-, 48-, or 96-hour TL_m value, the concentration that kills half of the test fish in the stated time under specified conditions. While TL_m values are a direct reproducible measure of txicity, they are not safe concentrations and cannot be used directly in regulating waste disposal. An approach has been suggested for the use of an application factor to insure the safe disposal of wastes. Several variables affect the magnitude of this factor. Allowance must be made for long-term or chronic effects of wastes, for fishes more sensitive than those tested, for different life-history stages, and for protection of fish food organisms. The relative importance of these factors may vary with the type of waste. Other variables such as pH, alkalinity, hardness, turbidity, temperature, and dissolved oxygen may have an effect on toxicity but are generally taken into account in well-designed bioassays.

Needed Research: There is a definite need to expand and intensify research along the above lines. While methods and apparatus have been designed for short-term (acute) and long-term (chronic) bioassays, further laboratory and field studies are needed to perfect methods, to give a better understanding of the major factors that affect toxicity, and to develop and test application factors in actual industrial-waste situations. There are so many variables that may greatly affect the toxicity of a material that the solution to a particular waste problem may lie in intensive investigation of that particular waste. For the above reasons, one of the major needs is a considerable expansion of toxicity research by industries which produce toxic products and release toxic wastes. Much information of value can also be produced in central laboratories. Among major specific needs in toxicity research are:

1. Development of methods.
    - a. Improvement in current methods of conducting laboratory bioassays (e.g. methods of adding oxygen when conducting acute bioassays with high oxygen demand effluents).
    - b. For conducting studies with different life history stages of fish (eggs, fry, etc.).
    - c. For conducting studies with fish-food organisms.

d. For studying tainting effects of chemicals on fish and shellfish.

e. For determining biologically safe concentrations.

2. Development of information -- General information which may be of value to industry, water control agencies and others should be developed for major types or groups of chemicals, as follows:
   a. Acute and chronic toxicity.
   b. Effect of water quality characteristics on toxicity (pH, alkalinity, hardness, temperature, dissolved oxygen, turbidity).
   c. Toxicity to different species of fish and their life history stages.
   d. Toxicity to major fish-food organisms.
   e. Concentration in tissues or organs and physiological or pathological effects.
   f. Effect on tainting flesh.

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403. Organic Contaminants Affecting Water Quality

Problem: Recovery and identification of organic contaminants in water, evaluation of their significance in water uses, and development of corrective procedures.

Background Information: Expansion in quantity and variety of commercial products in urban, industrial, and agricultural use has intensified the water-quality-control problem. Organic chemical industries have expanded more rapidly than population; their wastes frequently are unlike anything found in nature. Past experience in conventional waste treatment provides insufficient guidance for effective control of waste water from plastic, rubber, dye, detergent, and many other petrochemical operations. The heavy use of synthetic organics for agricultural purposes is reflected in the appearance of such chemicals in streams receiving farmland drainage.

Treated effluents from conventional waste treatment contain large amounts of organic residues which have not yet been fully described. Concentrations as low as one part in a billion of some chemicals can cause such water damage as taste and odor, off-flavor in fish, toxicity to fish, ion-exchange damage, foaming, interference with oxygen transfer, and interference with water-treatment processes. Toxicity to humans is a conceivable effect of such organic pollution.

We presently have some knowledge of these materials and of ways to measure, identify, and study their effects as water pollutants. But there are large gaps in this knowledge, particularly as to the capture and expeditious identification of persistent organic chemicals in surface and ground waters, and the determination of their behavior and ultimate fate. More intensive use of water makes it imperative that we be better able to measure, evaluate, and take appropriate corrective actions in response to the increasing number of organic contaminants.

Previous Work: Previous work on organic contaminants affecting water quality has followed several directions: (1) development of techniques for sampling and analyzing organics in water, (2) monitoring selected surface waters to determine occurrence, and (3) characterization in relation to origin, removal by waste treatment, effects on water uses, persistence, and removal by water treatment.

Possible Lines of Attack: There is need to intensify work along all current lines, especially: (1) To determine basic mechanisms by which organics reach water courses through land drainage. (2) To evaluate, by epidemiological and toxicological studies, the health hazards in using affected water supplies. (3) To develop better understanding of mechanisms of microbiological attack on organics as a basis for rapid solution of new waste treatment needs. (4) To develop improved methods of sampling and analysis for trace organics. (5) To develop improved methods for removing or destroying objectionable organics in waste waters and in water sources.

Facilities Needed: Specialized equipment for collecting and characterizing samples, laboratory-scale treatment facilities, and usual chemical and microbiological laboratory equipment.

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404. Sludge Dewatering with Synthetic Polymer Coagulants

The Problem: Factors influencing dewatering of sludge have been described in some detail in the references cited. However, mechanical sludge dewatering is still beset with numerous problems and in some instances unfavorable economics have forced the shutdown of costly equipment. The most severe problems have been associated with chemical conditioning and filter medium blinding. The advantages of reduced space requirements and flexibility of operation make sludge filtration attractive.

Previous Work: Genter reported on adsorption and flocculation as applied to sewage sludges some 25 years ago. This work led to elutriation as practiced today to reduce coagulant dosage. Unfortunately, elutriation is not a complete process in that it transfers a significant organic load to the secondary treatment system.

The rotary vacuum filter used for sewage sludge dewatering has been borrowed from the process industries. This operation is marginal because sewage sludges rank extremely low in the scale of filterable materials and the dewatered sludge has limited market value. Equipment manufacturers have made significant contributions in adapting this equipment to waste sludge dewatering. Improvements have been made in the filter medium and in operation procedures.

Potential Lines of Attack: Polyelectrolytes have been used both experimentally and on a plant scale at the Hyperion Treatment Works, Los Angeles. Separan 2610, a high molecular weight polyarylamide, resulting in a 25% savings on coagulants over a period of 2-1/2 years.

Most of the synthetic polymer coagulants that were tested required the concurrent use of an inorganic coagulant such as ferric chloride. Two experimental polymers, apparently ionic materials, were tested which reacted directly with the sludge particles and required no prior or subsequent coagulation by inorganic coagulants. These experimental polymers were very effective at dosages of 100 mg/1 or less. Organic polymers were also somewhat effective on unelutriated digested sludge and raw sludge. The very fine, slimy, and compressible sludge solids were converted by the polymer into easily filterable solids.

The development of material capable of effective action on all types of sludges normally produced represents a significant technical breakthrough in mechanical sludge dewatering. The company manufacturing these experimental synthetic polymer coagulants contends that the potential market in the sewage treatment field does not warrant investing in further development work. This work could be undertaken as a part of an academic program or as contract research. Results of this research should be applicable to both sewage and industrial wastes. Cooperation of Dow Chemical Company and American Cyanamid Company should be solicited.

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405. What are the Biologically Resistant Organic Compounds in Digested Sewage Sludge?

The Problem: There exists in digested sewage sludge a considerable portion of volatile solids that are not readily decomposed. The objective in sludge digestion is to reduce the quantity of sludge by destroying the organic matter by bacterial decomposition; therefore, if more of the volatile matter could be destroyed, the sludge disposal problem would be less difficult.

Previous Studies: A very resistant material, hair (keratin), has been used in a series of tests of the type indicated. These investigations showed that the hair is very resistant. It is realized that hair does not make up the organic matter that remains after anaerobic digestion.

Possible Approach: Isolate, identify, and quantitate organic compounds in their original form, as they occur in digested sludge. These compounds might then be subjected to modified methods of digestion, such as high temperature or pressure, aerobic action, or seeded cultures.

Facilities and Expense: The research can be carried out in an extensive way or it can be done on a very modest scale by several workers in laboratories scattered throughout the world.

406. The Behavior and Persistence of Enteric Viruses in Sewage Polluted Water.

The Problem: In recent years, a number of viruses of human origin have been found in sewage and in some natural waters. Recent technological breakthroughs in the culturing and identification of the virus has made such observations possible. At the present time, approximately 90 different enteric viruses have been recovered from domestic sewage. Little is known regarding the efficacy of commonly employed waste-treatment operations or the significance of natural purification agencies in destroying or removing the virus. Available information indicates that many viruses are highly resistant to most treatment processes and further that some species may persist for extended periods of time in receiving waters. There is need for a deliberate fundamental study of the behavior and fate of the virus during waste treatment and in receiving waters.

Purpose: The purpose of this research is two-fold. One is to evaluate the efficacy of the major functional operations employed in waste treatment in removing and destroying the virus. The second is to establish information regarding the relationship between virus survival and the principal environmental factors prevalent in most receiving waters.

Previous Studies: Very little has been done along the lines suggested above. Some work has been reported dealing with the killing efficiency of various types of radiation and some of the more common chemical disinfectants. Some work also appears to have been done with various types of filters and the use of certain chemical coagulants. Unfortunately, much of this work was motivated by reasons other than those of concern here and frequently invoked conditions which make translation or interpretation of experimental findings highly uncertain, if not impossible.

Possible Procedure: Suitable facilities for culturing and for identification of the virus would first have to be established. A limited number of viruses should then be selected for study purposes. Response, behavior, and survival of the test viruses would then be followed under the various environmental conditions of interest. It is contemplated that studies would be carried out employing activated sludge, chemical coagulation, anaerobic sludge digestion, the incubation of various natural waters, etc. Once general behavior patterns have been established, it should then be possible to pursue more detailed lines of attack, viz. addition of specific organics to activated sludge cultures, the use of auxiliary chemicals during chemical coagulation, etc.

Facilities: It will be necessary to establish facilities for culturing and handling viruses. A well-equipped laboratory for conducting more conventional research in the Sanitary Engineering field should also be made available. It is possible that these laboratory needs may be satisfied at some institutions through inter-departmental cooperation.

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407. The Utilization or Disposal of Biological Solids Produced in the Bio-Oxidation of Industrial Wastes.

The Problem: The treatment of large volumes of industrial wastes containing predominantly soluble organics requires (in the light of present knowledge) biological oxidation. In general, bio-oxidation is most effective, in the economic sense, when the maximum quantities of cellular material are being produced under conditions of steady-state oxidation and, consequently, growth. The final disposition of the excess biological solids, primarily bacterial cell material, is often the most difficult phase of the treatment system. In more than a few instances this problem of solids disposal has deterred action by an industry in treatment of its waste.

The magnitude of the problem is impressive and the trend most certainly is to increasing significance, particularly in metropolitan industrial complexes whose continued expansion depends in appreciable part on effective waste-treatment procedures.

Waste treatment usually involves capital outlay with no direct financial return in prospect. As a natural consequence, industrial management sometimes views waste treatment as a necessary evil to be attacked only when public or governmental pressure is brought to bear. It would, therefore, seem most logical to approach waste treatment from a viewpoint of recovery and/or utilization. Unfortunately, most waste streams by their very nature preclude such implementation. Dilute soluble organic waste streams from such industries as petroleum and petro-chemical processing represent a heterogeneous mixture of organic compounds. However, the conversion of these mixed organics to the common denominator of bacterial cellular material may offer an opportunity for effective and economic utilization of the waste products.

Previous Work: Most of the work involving excess solids utilization has been conducted on municipal wastes. Fertilizer has been the primary product from this material. In recent years animal and fowl feed supplements have been produced and vitamin B-12 extracted at least on an experimental scale.

Disposal of excess solids has involved anaerobic decomposition, vacuum filtration, spray drying, burning, and wet combustion.

Possible Avenues of Approach: The excess solids produced in bio-oxidation represent a significant energy potential. To lose this energy with no attempt to utilize the potential seems unrealistic. With the soaring advances in such technology as organic chemistry there must be a solution to effective utilization--perhaps in a direct chemical exploitation.

Another possible direction of investigation is the growth of algae, using the algal cells as food. Algae certainly have a potential for direct utilization as food.

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408. What is the Quantitative Effect of Algae and Other Aquatic Plants on Dissolved Oxygen Resources in a Stream Receiving Organic Pollution?

The Problem: One of the several "areas of ignorance" involved in evaluating the assimilative capacity of a stream is the determination of the quantitative effects that algae and other aquatic plants exert in the deoxygenation and reaeration processes continuously in operation in a polluted stream. Until a satisfactory measurement of the capacity of the receiving streams to assimilate pollution can be obtained, the extent of needed waste-treatment facilities can only be approximated. In view of the difficulties involved in measuring the assimilative capacity, many treatment plants are either over-designed with money wasted, or under-designed with the pollution problem not adequately solved. The development of a method for evaluating the quantitative effects of photosynthesis and respiration by aquatic plants in the presence of organic pollution would be of significant benefit.

Some Questions to be Answered by the Needed Research: When passively floating algae flow into a polluted zone, the turbidity produced by the pollution reduces the light intensity available throughout the stream vertical. At what light intensity does the production of oxygen by photosynthesis just balance the use of oxygen by endogenous respiration for each of the more common species of algae? What is the ratio of oxygen production to oxygen use at various light intensities, for each of the more common types of algae? Since concentrations of floating algae can be obtained from water samples taken just upstream from the influx of pollution, how can these concentrations, together with the distribution of light intensities measured on numerous stream verticals in the polluted reach, when combined with the flow of the stream in cubic feet per second, be used to compute the net rate of oxygen production or use by the algae in the polluted reach?

What light intensities and durations are required by algae that grow attached to the stream bed? At what levels of turbidity, as produced by the pollution, are the common species destroyed? What about the water mosses?

Since in darkness algae and attached aquatics use oxygen rather than produce it, would a stream with a high algal population have a higher or lower oxygen concentration at the low point of the oxygen "sag" during the hours of darkness? How can the answer to this question be reduced to quantitative values; i.e., how much, and under what conditions?

Previous Work: A vast amount of work has been done in the past, and much is currently under way, concerning various aspects of the growth, nutritional requirements, oxygen production, etc., of phytoplankton. The work has been done primarily on marine algae, on algae in clear lake waters, and on algae in waste stabilization ponds. Relatively little has apparently been done concerning relationships between algae and river self-purification. The available literature, however, will aid greatly in supplying background information necessary to the proposed research.

Promising Lines of Attack: Making use of the recently reported membrane electrode for measuring dissolved-oxygen concentrations in water, in connection with a recording polarograph for the continuous recording of changes in oxygen concentration, a great deal of information can be obtained in the laboratory at relatively low cost. Light intensities, turbidities, temperature, and other experimental conditions can be varied and the effects upon the dissolved-oxygen concentration in the reaction flask can be recorded directly. Using this equipment and technique, fairly large sample volumes can be used, while at the same time, the high sensitivity of the electrode makes possible the detection of rates of photosynthesis and respiration in samples containing relatively low concentrations of algal cells. A mere beginning on this kind of a research project, using the above equipment, has been made in the Stream Pollution Control Laboratory, Tennessee Valley Authority, Chattanooga, Tennessee, studying a few species of algae attached to rocks, and a few species of attached water moss. Results were very promising.

The Warburg apparatus might also be used in studying phytoplankton and possibly for studying attached forms.

Budget for Time and Money: The nature of the project is such that results could be obtained on a few species for a very reasonable expenditure of both time and money. Results on a limited number of species would be helpful until a more complete study can be made.

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409. The Effect of Adsorption by Particulates on Bacterial Pollution and its Relation to the Sampling, Analysis, and Interpretation of Pollutional Data

The Problem: Adsorption of bacterial indicators of fecal pollution on particulates and the effect of such adsorption in the collection of samples, bacterial analytical methods, and interpretation of data for polluted waters.

Reasons: Several bacteria in a single clump are counted as a single bacterium by usual procedures (Plate-counting procedure, membrane-filter method, or multiple-tube techniques) unless a uniform resuspension of the bacteria has been accomplished. Tentative evidence exists that simple shaking may, at times, increase adsorption rather than accomplish uniform resuspension of single bacterial cells. Adsorbed bacteria on particulates may settle out of water at certain periods and become resuspended during floods or other disturbances in the bottom sediment of rivers or impoundments. Sewage bacteria may be adsorbed on particulates in the receiving waters, resulting in unjustified low interpretation of the quantity of bacterial pollution. Survival rates of the indicator bacteria of fecal pollution (coliforms, streptococci, etc.) as well as those of the enteric pathogenic bacteria adsorbed on particles, are unknown and may be protected from natural purification processes when existing in clumps. The natural concentration phenomenon could produce at times health hazards in small portions of water owing to nonhomogenous suspension of bacterial pollution. Finally, sampling of the sediment may yield a more nearly correct estimation of the overall pollution than given by the usual "grab samples" of the surface water in surveys for stream pollution, shellfish water, water for recreational use, or raw water supplies for various treatment procedures for potable water production.

Previous Work: Quiescent sedimentation was observed to remove *Escherichia coli* from sea water, which after eight days could be recovered from the sediment according to G.T. Orlob. Rubentschik, et al believed adsorption of bacteria on soil particles stirred up by tide and wave action was the primary factor in the apparent removal of *E. coli* from salt lakes near Odessa, USSR. Adsorption of bacteria on finely divided particles of brick dust and insoluble chemical was accomplished by Kruger. A three-fold removal of coliforms on kaolin was reported by Braaflacht, and adsorption of soil bacteria on particulates as influenced by ferric and aluminum compounds was studied by Peele. Savage observed that mud samples from tidal rivers indicate evidence of pollution of the past several weeks. Several instances have been observed in rivers where only 10% to 50% of the streptococci could be recovered below a sewer outfall that should have been present when calculated on the dilution factor of the receiving stream.

Possible Procedures: Adequate bacterial procedures have been developed for coliforms, fecal coliforms, and streptococci in water and sewage. Work in the laboratory might consist of adding indicator organisms to artificial suspensions of known chemical composition and to natural waters for a study of particulate size, chemical composition, presence of various electroytes, pH, temperature, degree of agitation and other environmental factors on adsorption of bacteria. Simultaneous investigations might be made on the relative survival rates of suspended bacteria in fluid and adsorbed bacteria on various types of sediment. Field samples might include frequent examination of grab samples with corresponding sediment sample from rivers or lakes containing various turbidities. Methods might be developed for quantitative removal of bacteria adsorbed on various sediments.

Facilities: No special equipment is required aside from that found in the usual bacteriological laboratory.

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410. The Effect of Siltation and Turbidity on the Self-Purification Processes of Streams

The Problem: In regulating water pollution, considerable dependence is placed on the ability of the regulatory agency to assess the self-purification capacity of the receiving waterway. Many factors are taken into consideration such as temperatures, reaeration, oxygenation rates, flow, etc. Little, if any, attention has been given to the effects of silt loads and turbidity.

Self-purification is largely a biological process depending upon the development and rate of growth of numerous types of organisms. Environment is certainly a factor governing the growth and activity of these organisms. The process is the same as other biological processes and depends upon the establishment of a food chain including bottom forms, algae, plankton, and bacteria. Many of these organisms are dependent upon light. Others require a favorable stream bottom for attachment. Both of these factors are affected by siltation, scouring by sediment loads, and turbidity. How significant is this effect and can it be taken into account in assessing purification capacities?

Suggested Studies: The following suggestion appears to be one way that the study may be conducted: The project will require, first, an artificial or simulated stream after which the results may be projected to a natural water course where concentrations of silt and turbidity are variable. An artificial stream consisting of troughs, the bottoms of which are covered with material of a composition similar to that of natural stream has been used* for biological studies. Provision for the addition of variables, e.g. silt, sand, organic waste materials, and water velocity up to scouring rates, will be required. Other factors such as temperature, light, and water supply must be controllable. Time-velocity relationships can be controlled by variable recirculation of water of a given concentration of waste material.

The collection of data should include: sediment load, turbidity, light penetration, bottom flora, primary productivity (algal production), bacterial and fauna populations, rates of oxidation (BOD removal), etc. It is suggested that the biological data will be required to supplement and explain any conclusions regarding the rates of oxidation or BOD removal. Synthetic waste material which is completely soluble and readily oxidized will reduce such variables as sedimentation although the study may include waste-containing suspended organics. Since comparisons should be made with the reactions in clear streams, at least duplicate installations will be required.

The results of the pilot-plant study will influence the application to field conditions.

411. What Specific Types of Organics Escape Conventional Complete Sewage-Treatment Processes and What Are Their Characteristics:

The Problem: As more and more demands are placed on the water resources of this country the need for the complete reclamation of water for water supplies and other uses will become imperative. The need for "Ultra" treatment of sewage is not far distant. The complete removal of organics from sewage may be required for many subsequent water uses. At least, a removal in excess of that apparently possible by existing conventional processes will be in demand to meet future quality criteria. This treatment may be accomplished either by the development of new processes or improvements or additions to existing ones.

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The efficiency of sewage treatment in removing organics is usually measured by the reduction in 5-day BOD. Removals of 90 to 98 per cent are often indicated by so-called "complete" processes on the basis of the 5-day BOD. Yet other tests for organics, such as carbon analysis, do not show this high efficiency. Ultra treatment will require the removal or reduction of these organic compounds which apparently escape the best-known processes. The first step in the development of new or added treatment to remove these compounds is to identify them at least as to types and characteristics. Such information may be the clue to ultra treatment.

Possible Lines of Attack: There are a number of methods by which the organics in highly treated sewage effluents may be concentrated and identified. A method which appears to have merit involves the carbon filter presently used by the Public Health Service for the collection of basic data in streams. In this case, carbon filters might be installed to take effluents from well-operated and efficient secondary treatment processes. Identification is accomplished by extraction and analysis, including chromotography.

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1. "Manual for Recovery and Identification of Organic Chemicals in Water," Robert A. Taft Sanitary Engineering Center (May, 1957).

412. Comprehensive Study of Organic Pollution Die-Away and the Influence of Temperature, Flows, etc., in Waterways

The Problem: To determine the die-away variables on different types of common pollutants such as aliphatic hydrocarbons, aromatic hydrocarbons, chlorinated aliphatics and aromatics, phenolics, etc.

Significance: Pollution control without purpose is an economic luxury that this country cannot afford. It, therefore, behooves the pollution engineer in designing an abatement plant to know what happens to the pollutants in the effluent as they flow downstream. This question requires a knowledge of the die-away variables. The effects of stream flow, concentration, ambient temperature, water temperature, etc., are extremely important if downstream water use is to be protected. A reasonable understanding of the ultimate fate of prospective pollutants in a water course can be of great importance in industrial plant location, location of fresh-water inlets, recreational facilities, etc. Information on die-away is, therefore, a virtual necessity in pollution regulation as well as being extremely helpful to abatement plant designers.

Previous Work: There is at present a limited amount of useful information on this subject in the literature. However, most of this information concerns the die-away rates of a specific waste in a specific water course. Such information is of use to those working in the section of the water course in question. What is needed is a laboratory method of developing information on groups of compounds that can be used for predictions, taking into consideration the variables that exist for the river in question. A great deal of interpretation would be necessary with information of this type. Such interpretation of laboratory information is certainly not new to the science of public health. For many years the relative hazards created in handling certain chemical substances have been interpreted from laboratory data obtained using small animals. The relationship between the effect of the chemical under study on laboratory animals and humans is a matter of interpretation. In the field of water-pollution science, similar interpretations are made, and more such procedures will be necessary if this field is to graduate to a discipline of high stature.

Possible Avenues of Approach: The research might well begin on a limited scale with one or two groups of compounds. Experimental data can be gathered on the reaction rates for degradation and stabilization of specific substances under variable conditions of temperature, dilution, area-volume relationships, dissolved oxygen, biological seeding and associations, catalysis, pH, etc. Standard procedures might be developed so that other laboratories could participate and expand the total knowledge of this vast subject.

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413. Thickening and Dewatering of Sludges Produced From Clarification of Industrial Effluents

The Problem: Clarification of effluents from the manufacture of pulp, paper, paperboard, textiles, chemicals, and other manufacturing, produces in some cases sludges that are hydrophylic in nature and are highly resistant to thickening and dewatering. Most of the unit processes now employed for sludge dewatering, such as filtration and flotation, are successful only to a limited degree, if at all, when operating on these hydrous residues which contain as little as 1 per cent of dry solids.

The sludges produced by biological oxidation of organic wastes by the activated sludge process, and others, are particularly troublesome to handle. This represents a serious future problem since oxidation treatment is becoming more and more common for handling industrial wastes.

Present Status: At present, land disposal is the most common means of disposing of such sludges. This method is only satisfactory where relatively small volumes are involved since air drying must be depended upon to concentrate the solids. The bulk of the water held by them will not separate and seep through the ground, even after repeated freezing and thawing. They rapidly form a surface film over sand and gravel which prevents the flow of rain water or any other free water added to them to seep through.

Some success has been obtained recently with centrifuges designed specifically to handle such sludges. The present limitation of these machines is that those which make a high separation of the solids from the liquid do not dewater to a sufficiently high degree and those which do, fail to achieve a desirably high solids separation.

Chemical conditioning agents such as alum, ferric chloride, the polyelectrolytes, and so-called "coagulant aids" have some effect but even at high dosages have not proven to be satisfactory dewatering agents in many instances.

If sufficient inorganic filler type material such as fly ash is added to gelatinous sludges, the hydrogels are adsorbed on the filler and the mass becomes dewaterable by filtration. However, such materials are seldom available in sufficient quantity to handle the amount of sludge to be dewatered, are frequently abrasive and require some processing, such as fine screening, before they are suitable for use.

Potential Lines of Attack: A study of the literature covering hydrogels with the thought in mind of obtaining leads for research and acquainting investigators thoroughly with the basic concepts should be made. Particular attention should be given to unusual methods such as electrodialysis, supersonic vibration and others, which while they may not appear promising in the original form, have in themselves been greatly improved and, in their present form might prove effective. Very little has been done using organic dehydrating agents and solvents for dewatering. Investigation of these classes of compounds might prove fruitful.

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1. "A Description and Critical Discussion of Selected Methods Applied or Being Applicable to the Dehydration of Hydrogels Similar to Those Obtained on Clarifying Some White Waters", National Council for Stream Improvement, Tech. Bul. No. 74, (1954).
2. "New and Basic Research Approaches to Pulp and Papermill Liquid Effluent Treatment", National Council for Stream Improvement, Tech. Bul. No. 104, (1958).
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4. "Freeness of Paperboard Stock as Affected by Biological and Other Factors", National Council for Stream Improvement, Tech. Bul. No. 96 (1957).
5. "Drainability and Dewatering of White Water Sludges", National Council for Stream Improvement, Tech. Bul. No. 35, (1950).

414. Bacterial Flora of Polluted Waters

Objectives: Identification and enumeration of bacteria responsible for the purification of polluted waters in streams and artificial biological treatment processes. Polluted waters include both domestic sewage and industrial wastes.

Reasons: A great deal more information is needed than is presently available as to the identity of bacteria responsible for the purification of polluted waters under natural or artificial conditions. The overall biochemical reactions, their rates, factors affecting the rates, and the intermediates and end-products formed in the stabilization of polluted waters by mixed populations has been the direction of most of the investigations up to the present. The task has seemed formidable to undertake because of the inadequacy and inapplicability of methods developed in other fields of bacteriology to the aquatic bacteria. But unless a better insight is obtained of the types of bacteria, their numbers, and activities, the succession of types, their interrelationships, their biochemical activities, and effect of the various environmental factors prevailing in streams and artificial treatment processes, little progress can be expected in the future for the control and stimulation of the rates of reaction in the stabilization of the pollutional materials.

Previous Work: Previous work on the microbiology of polluted waters has followed two directions:

1. Identification and enumeration of microscopically identifiable forms of plants and animals such as algae, diatoms, protozoa, etc., as indicator organisms of pollution.
2. Studies concerned with the occurrence and survival of coliform and other enteric bacteria from the standpoint of public health.

Possible Methods of Approach: Suitable methods and culture media will have to be developed for the isolation, cultivation, and enumeration of strictly aquatic bacteria. Once this is accomplished then the role played by these bacteria, their succession, and biochemical activities can be studied under controlled laboratory environmental conditions and from samples obtained from streams and biological treatment plants. Effects of pollutants other than domestic sewage, such as various industrial wastes and radioactive materials, on the bacterial flora and their activities might well be studied.

Facilities: No special equipment is required aside from usual bacteriological equipment such as incubators, autoclaves, etc.

415. Instrumentation for Continuous Monitoring of Polluted Streams

The Problem: Because the amount of damage from pollution of streams is not continuous from industrial and domestic establishments, it is necessary to evaluate the effects of pollution sources under many stream conditions and over a considerable period of time and even during different seasons in order to understand adequately the effect that any given industrial waste may have upon a polluted stream. When there are several sources of possible damage or pollution, the combination of several variables requires more data. Because of the rapid changes in river quality from slugs of chemicals, only continuous analysis with electrical recording of sensing elements in the flowing body of water can adequately monitor the problem of stream pollution.

Present Status: The determination of pH in a stream is made difficult by the presence of ground in contact with the flowing water sample, by changes in water temperature, and by light-intensity variations. The determination of conductivity is interfered with by biological growths, by slimes on electrodes, by changes in temperature, and by motion which disturbs the diffusion pattern of ions between electrodes. In many instances, the recording of temperature is extremely important in the detection of an industrial waste discharge, as well as being necessary for understanding of other instrument data, such as pH and conductivity. The elevation of temperature by power generators, the discharge of high-temperature waste from certain industries, and the chance discharge of slugs of high temperature from reaction vessels frequently modifies the pollution in a small stream. Polluted streams that receive high-temperature wastes should be checked continuously for temperature elevation to obtain the total pollution picture. The amount of difficulty in recording various items depends not only upon the instruments but also on such problems as strong stray electrical currents from large electromagnetic installations from which power to operate the instruments must be obtained. Furthermore, the water can be obtained most easily from the river near a bridge with power lines, or at pumping stations where stray currents cause the operation of electronic equipment to be very difficult. To record the minor variations in pH, use of river pumping stations for protecting equipment is desirable, but it makes the recording extremely difficult because of so many variable electrical factors.

Potential Techniques: It is hoped that instruments might be developed through research which (a) can be left in the stream, or (b) can be floated on the stream, or (c) may be supplied by water from a pump very close to the stream. The instruments should yield information continuously of the minor and/or major changes in the quality of the water along with an indication of the time when the variation in that quality occurred. These items of information might include conductivity, temperature, pH, dissolved oxygen, and suspended solids (or turbidity). These materials are now determined electrically in the laboratory and it is quite conceivable that each of them can be monitored on a continuous basis in the stream.

The possible use of short-wave radios for short-distance transmission of a low-intensity radio signal is considered possible. The type of signal that has been transmitted from satellites or balloons for weather monitoring, radiation intensity, and light intensity might be handled quite readily if the proper amount of money and equipment could be assembled and utilized effectively.

Area of Application: Impoundments create changes in water quality that have no relation to pollution. The restoration of dissolved oxygen and/or temperature within and downstream from impoundments has been studied intermittently. Dissolved oxygen may change from 1 to the saturation value of 7 or 8 mg/l. The study of the single factor with this one variable can be carried out on streams below river impoundments because a second factor, B.O.D. from pollution, is lacking. For this particular study it is invisioned that a team will be needed. River Control authorities should have a number of pollution patrol stations on rivers where records of information could be obtained, particularly in order to implement court orders and/or injunctions which prohibit the maintenance of a particularly poor quality water at any given point.

References:

1. Proceedings of the Symposium on Water Quality Measurement and Instrumentation, U.S. Public Health Service, Cincinnati, Ohio (August 1960).

416. Adsorption, Desorption, and Ion-Exchange in Ground Water Flow

The Problem: Many regions rely heavily upon ground water for domestic, industrial, and/or agricultural water supply. The ground water, in many instances, is being recharged naturally or artificially from treated sewage, industrial wastes, or polluted surface streams. When such recharging water passes through soil of various chemical composition, and under diverse conditions of aeration, deaeration, and redox potentials, certain ions are likely to be adsorbed, desorbed, or exchanged with the soil. These phenomena need to be investigated and evaluated with respect to the numerous variables.

Background Information: Soil chemists and soil physicists have accumulated a wealth of information on the behavior of moisture in the interstices of soil in the plant zone. Most of this information deals with the common ions (calcium, magnesium, sodium, potassium, chloride, nitrate, sulfate, and bicarbonate) and their relation to plant needs. Not much is known, however, about the less-common ions such as chromates, borates, cesium, etc.

In addition, geologists have investigated the chemical phenomena associated with the various minerals, but it is still difficult to translate geological data into a form that can be used by water chemists and engineers. Nevertheless, all available information from the literature of soil chemists, physicists, and geologists should be studied.

A new factor in the problem is the resistence of alkyl benzene sulfonate and related synthetic organic compounds to bio-chemical degradation. There have been instances where ABS has travelled through thousands of feet of soil; yet, it may be subject to adsorption and possibly to biochemical stabilization under the proper conditions. The same problem applies to hydrocarbons, chlorinated organics, and other substances.

Possible Lines of Attack: This problem might be studied by *in situ* investigations of known instances where polluted water is travelling through aquifers. In such cases there should be a thorough investigation of the soil characteristics as well as chemical analyses of the influent and effluent water.

Another approach, one that lends itself better to scientific control of the many variables, is to set up in a laboratory or field station numerous columns containing soils of various known composition. Each column could then receive water of a prescribed chemical and/or biological load, at a predetermined rate of filtration. The ability of the soil to adsorb or exchange ions could then be evaluated by assaying the effluent. At the end of the experiment the new chemical composition of the soil could be determined, as a check on the differences between influent and effluent.

There are several other ways to attack this problem and each method is subject to various modifications and innumerable experiments, if a wide variety of soils is to be investigated under many conditions of flow.

References:

1. Proceedings of the Conference on Ground Water Pollution, U.S. Public Health Service, held in Cincinnati, Ohio in April 1961.

417. The Sanitary Significance of the So-Called "Aftergrowths" of Coliform Organisms in Waters Receiving Treated Sewage Effluents

The Problem: When sewage effluents are treated with chlorine to produce a very low coliform content and discharged into surface waters, the coliform populations of the receiving waters frequently increase in total numbers to almost that of the sewage before treatment. Do such coliforms that have apparently been produced in the receiving waters have the same sanitary significance as coliform organisms derived directly from domestic sewage? Or, are they the same coliforms that were supposedly killed by chlorination but have been resuscitated in the receiving waters?

Previous Work: Evidence is available to indicate that pathogenic enteric bacteria exhibit the same order of resistance to disinfectants and other deleterious environmental conditions as do the coliform organisms. However, because of inadequate enumerating procedures for pathogenic bacteria and because of other technical difficulties, attempts have been unsuccessful to compare quantitatively the relationship of pathogenic bacteria with coliform organisms in polluted waters under varied conditions of treatment, disinfection, dilution and storage.

Taylor demonstrated that *Escherichia coli* would multiply on yarn in water temperatures of 13°C and that some *Salmonella* and *Shigella* multiply at the same temperature under similar conditions. Greenfield showed that coliforms from soil were more resistant to low temperatures than coliforms from the warm-blooded animal gut. Other evidence in the literature suggests that enteric pathogenic bacteria may multiply under the same conditions as the coliform group. Thus, the aftergrowth problem is concerned with temperature of the environment and relative competition for the available food supply.

Suggested Avenues of Research: Using methods available for the differential enumeration of coliform bacteria, one might determine quantitatively the numbers of fecal coliforms and nonfecal coliforms in the "aftergrowth" populations. These results would show the types of coliform capable of growing or being resuscitated under the temperature and nutritional conditions prevailing. It might also be helpful to determine the limiting temperatures for the growths of pathogenic enteric bacteria, fecal coliforms, and nonfecal coliforms in pure and mixed cultures. Should the "aftergrowth" populations exhibit altered growth characteristics, a less-significant sanitary implication might be justified.

Facilities: In addition to normal sanitation laboratory equipment, water bath incubation at 45°C and facilities for chlorination and variable storage temperatures will be required.

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1. Taylor, Jour. Appl. Bact. **17**, 104 (1954)
2. Greenfield, Jour. Inf. Dis. **19**, 647 (1916)

418. The Effect Upon the Domestic Consumer of Trace Chemical Elements and Compounds in Water Supplies

The Problem: The problem of chemical contamination of drinking water occurs everywhere, but is probably more prevalent in areas being served by surface water supplies. The problem is caused by an increased reuse of waters contaminated by greater industrial and agriculture uses. A solution is needed so that we may understand the effects of these contaminants upon people before we proceed any further in the indiscriminate disposal of such substances into surface waters. Some illnesses may actually be caused by consuming these contaminated waters. Adequate river dilution has kept the problem from becoming more serious to date. Unfortunately, this dilution will be less effective in future years. The trend will be toward more concentration of these contaminants with the possibility of ill effects resulting from the use of these waters.

Aims: The effects of these contaminants upon human beings should be ascertained. The medical profession should be encouraged to cooperate with the sanitary engineer in undertaking this research. An approach similar to that used in the cigarette situation and fluoride consumption eventually must be used. Controlled populations using contaminated and non-contaminated waters should be studied.

Present and Past Efforts: Bibliographies of the effects of trace metals on plants, animals, and bacteria were collected in one study at the Kettering Institute. Methods for analyzing waters for trace quantities of insecticides have been proposed by the Taft Center at Cincinnati. A conference was held on this subject by the USPHS in 1960. Conjectures have been made on the possible effects of contaminants in water supplies. Little or no effort has been made in organized research on this problem.

Potential Lines of Attack: We can be hopeful of a solution to this problem because it is a necessity for human existence. Research has been thwarted up to now by (1) analytical techniques, (2) lack of cooperation of the engineering and medical professions, (3) reluctance to utilize humans as subjects of the research efforts, and (4) the magnitude of the problem. The USPHS can do a great deal in eliminating the barriers that exist between the two professions and in providing analytical methods for trace elements. Educational institutes and private foundations for research can instigate controlled research. Four questions must be answered: (1) what are the toxic elements and compounds; (2) how much is being removed by present water treatment methods; (3) what are the human toxic limits of these elements and compounds and (4) how may we remove them from water supplies with greater efficiency?

Other Pertinent Considerations: The work might be carried out at many locations, but controlled centrally. This is not a new problem. It has been suggested by many scientific persons - mainly at the progressive Taft Center - and inferred by other "laymen". But, suggestions and inferences are not sufficient. They must be augmented by positive and immediate action. It is quite a paradox that the Secretary of Health, Education, and Welfare issued orders preventing the human consumption of contaminated cranberries and poultry which are eaten by a portion of the people, but has not yet considered in our present day the consumption of contaminated water by all the people.

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1. Proceedings of the Conference on Physiological Aspects of Water Quality, U.S. Public Health Service, Wash., D.C. (Sept. 1960).
2. "Water Quality Criteria", Publication No. 3, California State Water Pollution Control Board, Sacramento, (1952).

419. The Biochemical Degradation of Sulfonated Lignins

The Problem: Sulfonated lignins constitute a large proportion of the solids in spent sulfite liquor. They are remarkably stable in strong and dilute concentrations, so much so in fact that they have been used effectively as tracers in estuarial research. Yet, there must exist in nature some combination of organisms that symbiotically can attack these compounds readily and degrade them to simple inorganic substances with the concurrent synthesis of protoplasm.

Background Information: When a ton of wood is pulped by the sulfite process, approximately one-half ton of cellulose pulp is obtained. The other half ton of original wood, along with the chemicals and water used for cooking or digestion, constitute the by-products of pulping, collectively known as sulfite waste liquor (SWL) or spent sulfite liquor (SSL). In a typical calcium-base SSL, lignin sulfonic acids comprise about 65 per cent of the total solids, fermentable sugars about 15 per cent, non-fermentable sugars about 5 per cent, and calcium about 7 per cent. The fermentable sugars have been used in a few locations for the production of yeast, alcohol, and other by-products, although the economics of recovery are quite marginal. No significant use has been found for the largest waste component, the sulfonated lignins. These compounds comprise a multitudinous complexity about which little is known. They have molecular weights ranging from a few hundred up to about 100,000, with a median of about 10,000. It has been demonstrated that they are exceedingly complex combinations of benzene rings, methoxy groups, hydroxyl ions, and sulfonate linkages. An insight into the complex chemistry of lignins has been presented by Nord and Schubert.

Two facts lead to the hypothesis that sulfonated lignins can be degraded biochemically. First, they are organic compounds, consisting almost entirely of carbon, hydrogen, and oxygen atoms. Second, lignins in nature are decomposed by saprophytic organisms; otherwise every tree that ever fell in a forest would still be lying there. The lignins in a decaying log differ from those in SSL only in that the latter are in solution rather than exposed to the atmosphere, and also, the latter have acquired sulfonate linkages. These sulfonate groups should not interfere seriously with biochemical attack. Odlang and Tollefson have each shown that SSL will stabilize slowly, with a higher rate in dilute concentrations; but the mechanisms of degradation and the organisms responsible for it are not well understood. It is believed that the higher fungi are the major organisms involved, but little is known about the intermediate metabolic products, the pathways of decomposition, or the synergistic action of bacteria. If these phenomena were understood, it might be possible to reclaim by-products economically from the biochemical decomposition of SSL.

Previous Work: Not much has been accomplished along this line of research, for the subject has been virtually neglected. Tyler et al have studied the treatment of SSL on trickling filters and other attempts have been made unsuccessfully to stabilize SSL with activated sludge. Gottlieb and Pelczar have reviewed and summarized current information about the microbiological aspects of lignin degradation. Adams and Ledingham conducted limited experiments on this phenomenon.

Possible Lines of Attack: This subject is so broad and so complex that almost any approach would provide some new information to help unlock one of nature's most-closely guarded secrets. Efforts might well be made to isolate and identify the organisms that are present in dilute concentrations of SSL undergoing stabilization. Similarly the fungi, bacteria, and other forms associated with logs decaying in water could be determined. With these forms known and cultured, it might be possible to find combinations that will decompose SSL readily in aerobic or anaerobic atmospheres, with or without abundant surfaces of attachment. The optimum conditions and combinations of organisms might be determined.

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420. The Rate of Reaction Between Dissolved Oxygen and Reduced Sulfur Compounds

The Problem: Various industrial wastes, particularly those originating in the manufacture of paper, contain incompletely oxidized compounds of sulfur. In the conventional method of determining dissolved oxygen, these substances react with the analytical reagents employed, and decrease the apparent concentration of dissolved oxygen. One result of this situation is the erroneous impression, which appears to be rather widespread at least in the sanitary field, that oxygen and reduced sulfur compounds cannot coexist in solution under any circumstances. Difficulties also arise in attempting to evaluate the effects of such waste materials upon receiving waters, and in attempting to control their treatment.

Analytical methods are now available which permit the separate determination of dissolved oxygen and at least some of the reduced sulfur compounds without mutual interference. These procedures make it possible to measure reaction rates, and the effects of such variables as pH, temperature, concentration, and the presence of other substances.

Potential Lines of Approach: It would presumably be desirable to start the work with pure solutions. By using modifications of published polarographic techniques, it should be possible to follow the change of concentration of one, or perhaps more than one, of the reactants as the reaction proceeds. Interpretation of the reaction rate curves would employ established techniques of physical chemistry. After studying the effects of a number of variables, and several pure compounds and mixtures, it would be desirable to extend the research to industrial wastes containing these substances, and to attempt to correlate the results with the concentrations of reduced sulfur compounds found in the water.

Facilities and Personnel: Aside from ordinary analytical equipment, a polarograph will be required. The investigator should have a sound background in the fundamentals of chemistry. The project might lend itself well to university graduate work employing a student with a chemistry degree working under a competent director. The research could cover from one to three years, depending upon the background of the investigator, the percentage of his time available for this work, and the range of compounds, conditions, and wastes examined.

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421. The Effects of Photosynthetic Plankton Upon the Pollutional Loading Capacities of Surface Waters

The Problem: Quantitative evaluation of the effects of photosynthesis on the assimilative capacities of surface waters.

Background: It is well recognized that the activities of algae and other photosynthetic inhabitants of surface waters contribute important quantities of dissolved oxygen to the economy of the system in which they live. However, in doing so, they also create *de novo* equivalent quantities of organic matter. At the completion of their life cycle, or under conditions which inhibit photosynthesis, reoxidation of the organic matter imposes a drain upon the dissolved oxygen. Thus, the net result varies with time, and indeed under some conditions dissolved oxygen can be totally depleted by this effect alone.

More information is needed on the quantitative aspects of these effects, in order better to assess the capacity of a given body of water to receive, absorb, and purify organic wastes without undesirable effects upon its condition.

Prior Work: Considerable work has been published concerning the production of organic matter by photosynthetic plankton. A few references to work of this type are cited below. In general, however, the data have not been collected and interpreted in such a way as to define the capacity of the water to deal with addditional organic loading in the form of treated or untreated waste effluents.

Suggested Avenues of Approach: Perhaps work on this project could best proceed from the specific to the general. That is, the initial work might involve evaluation of the effects of photosynthesis in certain actual bodies of water. The major part of this phase of the work would be done in the field. After a sufficient number of such specific studies, an attempt to deduce general principles would be in order. At the beginning of the work, some time would undoubtedly have to be spent on the development of methods.

Organization: The project as sketched above is very broad, and to attempt it as a whole might prove to require facilities beyond those of most research organizations. However, it could be easily subdivided into a number of more limited parts. In fact this might be best, since the geographical location of the waters studied is an important factor in financing the work. Some or all of these parts might serve well as university thesis material, and other organizations may find parts of the project equally well adapted to their facilities.

If it is feasible, direction of the project by some coordinating agency or group might simplify the integration of results from various sources.

It is difficult to estimate the total duration of the project, since so much depends upon how many studies can be conducted simultaneously. Certainly the study of each body of water should be extended over at least two or three annual growth cycles to avoid distortion of results by meteorological peculiarities of a single season.

Personnel: The disciplines involved are certain specialized branches of chemistry and biology, and at least the principal investigators should have suitable backgrounds of training in these fields. At the same time, the work could serve to train other members of the team in these specialities.

Facilities: The ordinary facilities required for studying the chemistry and biology of natural waters should be adequate for this work. Field equipment would be necessary, however.

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422. Characterization of Taste and Odors in Public Water Supplies

The Problem: The mode of expressing results of taste and odor observations is strictly of a qualitative nature. It is based largely upon the olfactory sense without any guide beyond human ability to associate and describe personal reaction. As a result, odors are often given such descriptive terms as wet goat, wet dog, manurial, rotten egg, spoiled fish, etc. In addition, the intensity of the odor is often rated on an arbitrary scale ranging from 1 to 5. Such a system, of course, depends to a great degree upon the accuity of the nose of the observer, his past experiences, and his ability to describe his reaction accurately.

Industrial effluents are frequently blamed for unwanted tastes and odors in potable water. This blame may be justifiable sometimes, but in many instances the fault is due to non-industrial impurities in the water, or to improper processing at the water-treatment plant. The subjective nature of taste and odor has confused this problem, and it is desirable that a comprehensive study be made, at as fundamental a level as can be reached. The whole problem of taste and odor needs re-evaluation and continued study.

Background Information: One has but to look at the available literature on taste and odor today to note the considerable confusion that exists when it comes to describing them. Little has been accomplished in recent years to improve this situation. Although a considerable amount of work has been done to develop the threshold method for determining the intensity of odors, no such effort has been made on odor characterization. Research organizations have a tendency to shy away from work on this problem, pleading complexity. It must be admitted that this is a highly complex problem encompassing many disciplines, but using complexity as an excuse is not the scientific approach to any problem.

Possible Lines of Attack: One possible line of attack would be to develop a set of standard odors for use in so-called "sniff-sets". Such sets, similar to those used by the Army Chemical Corps for recognition purposes, could be used to calibrate human response in describing odors. These "sniff-sets" should cover only the major odor types such as sulfurous, hydrocarbon, medicinal, woody, etc.

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423. Identification of Compounds Causing Taste and Odors in Mountain Streams

The Problem: In the Rocky Mountain area, on occasion, rather strong taste and odors are encountered when chlorine is applied to clean water derived from high forested mountain areas. The taste and odor is somewhat like that caused by phenol and positive tests for phenol can usually be obtained. It is suspected that the compounds are phenolic in character and probably result from the natural pitches exuded by conifers or decomposition of pine needles. Knowledge of the specific materials involved should help in providing better disinfection of such water supplies.

Background Information: The importance of phenol and many related compounds in producing taste and odor problems in public water supplies following chlorination has been recognized for some time. This difficulty has led to the formulation of rather strict regulations concerning the discharge of phenol-bearing industrial wastes to waters used for public water supplies. Some investigators have held that phenolic-type compounds are produced in nature and that industry is not always at fault. The problems occurring in waters derived from mountain sources would support this claim.

Possible Lines of Attack: The first step in attacking this problem would appear to be one of isolating and concentrating the odor-producing substances. A reasonable procedure would be to utilize the activated-carbon adsorption technique as developed by research workers at the Robert A. Taft Sanitary Engineering Center of the USPHS at Cincinnati, Ohio. The adsorbed material can be removed from the activated carbon by extraction with solvents and then subjected to standard tests for characterization of the organic components.

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424. Septic Tank Seepage Fields as Sources of Algal Nutrients

The Problem: Inadvertent fertilization of aquatic areas by plant nutrients contained in human wastes is despoiling many valuable recreational lakes, reservoirs, and streams through stimulation of nuisance blooms of algae and rooted aquatic plants.

As populations increase, the value of aquatic recreational areas will diminish unless something is done to control fertilization by human wastes. The role of sub-surface sewage-disposal systems in contributing to this problem is unassessed.

Background Information: During the past two decades there has been a growing awareness that many of our lakes and reservoirs are suffering from over-fertilization which causes them to produce prolific and often obnoxious blooms of algae. Oftentimes, the excessive fertilization can be attributed to human wastes that expand the plant nutrient budget beyond the assimilative capacity of a well-behaved body of water. The obvious solution in most instances is to prevent the admission of such fertilizing matters to the body of water. Such prevention can often be accomplished for that portion of human wastes carried by municipal sewers by diversion or special treatment to remove plant nutrients; but little can be done about wastes discharged to seepage fields.

Many recreational lakes and reservoirs are nearly surrounded by homes, cottages, and commercial establishments that depend upon septic tanks and seepage fields for disposal of human wastes. No assessment of the nutrients actually passing through the soil to reach the surface waters has apparently been undertaken in this country. The Swiss have been studying the eutrophication of lakes and may have studied this phase of the problem.

Possible Lines of Attack: Lysimeter studies employing various depths of soil from a given area and soil types from a wide area could be made to measure adsorptive and exchange capacity.

Field studies conducted at actual installations of some years standing would provide extremely valuable information. Consideration should be given to year-round versus summer usage of disposal facilities and attention should be directed to the influence of trees and other vegetation as protective devices.

References:

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425. Permissible Plant Nutrient Levels in Streams

The Problem: Sanitary sewage and many industrial wastes, treated and untreated, carry significant amounts of fertilizing matters into receiving waters. In the case of sanitary wastes, a large part of the plant nutrient materials removed by cropping of our agricultural lands reaches the sewers of our cities via the digestive tract of man. In addition, the nutrient level of phosphorus in sanitary sewage, and in some industrial wastes, is materially increased by the phosphates contained in synthetic detergents. Sewage and industrial-waste treatment plants are not normally designed to remove plant fertilizing materials, such as nitrogen, phosphorus, potassium, etc.

Discharge of human and industrial waste waters to lakes and reservoirs has led in many instances to the development of offensive algal blooms. One means of relieving this situation has been to divert waste waters from lakes and reservoirs to streams. The added fertilization load on the stream, in some instances, has stimulated the growth of rooted aquatics to the extent that stream flow is impeded and excessive oxygen demands are placed on the stream by respiration of the plants during the night.

Background Information: The relationship of primary productivity of surface waters to mineral nutrients present in the water has been quite thoroughly explored, particularly with respect to tolerable levels, i.e. levels which are insufficient to support the development of so-called nuisance blooms. The special role of phosphorus and its relation to supporting blooms of nitrogen-fixing organisms has also been quite thoroughly explored. These studies have led to the development of the concept of permissible nutrient budgets and has served as the basis of decisions to divert sewage or sewage-plant effluents from lakes to streams, or to remove nutrient materials as part of the treatment process.

Many sewage treatment plants discharge effluents into small streams. There may be no opportunity for diversion and hence engineers must solve the problem by meeting the requirements of the receiving stream. These requirements must be known as a basis for proper design.

Possible Lines of Attack: This problem might be attacked by either of two approaches. One would be to place a number of natural streams under survey and, through observations of stream-bed characteristics, stream flow, chemical composition of water and biological phenomena, to establish empirical criteria of permissible nutrient loadings. The second approach would be experimental and would, of course, require a suitable source of stream water of reasonable quality, an area for development of experimental streams, and a source of treated domestic sewage.

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426. Requirements for Protection of Water Reservoirs from Sub-Surface Sewage Disposal Systems

The Problem: A 1,000-foot set-back from reservoir high-water lines is generally recognized as the minimum acceptable for the construction of residential areas using sub-surface sewage disposal systems of the septic-tank type.

In most rural and suburban areas, it is impractical for a water utility to purchase and control the entire watershed of a reservoir basin. The high cost of property is often used as an argument for decreasing the set-back requirement while the safety of the public health is used as an argument for increasing the requirement.

Background Information: The history of water-borne disease epidemics has demonstrated time and again the role of wastes from the human body. With few exceptions, these epidemics have been a result of the failure of barriers erected to remove or destroy harmful organisms, a short-circuiting of the barriers, or inadvertent contamination of water supplies because of faulty distribution systems.

Recent studies have indicated the distance of travel of coliform organisms in soils to be a matter of only a few feet and most of that is downward in cases where sewage is injected above the water table. The information is less well defined where ground waters are the recipients of bacterial-laden sewage.

Possible Lines of Attack: It is to be anticipated that field investigations conducted in areas having been served by soil absorption systems for a period of years will yield the most reliable results, because of natural undisturbed soil conditions.

The investigations should be made in soils of various types, including systems entirely above ground water and those influenced by ground water, permanently or fluctuating.

Because of the growing need for information on transmission of the enteric viruses, it is important that studies be conducted to evaluate their transmission in soils as a part of this study.

References:

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427. Mechanism of Hydrogen Utilization in Depolarization of Corrosion Cells by *Desulfovibrio desulfuricans*

The Problem: Corrosion of ferrous metals represents a great economic loss as well as an unnecessary wasting of natural resources. Losses from corrosion produced by sulfate-reducing bacteria represent a significant part of the total. A better understanding of the biochemistry and physiology of these organisms may make it possible to devise new and more effective methods of controlling corrosion of this type.

Background Information: The sulfate-reducing bacterium, *D. desulfuricans*, has long been known to accelerate the corrosion of iron, and iron alloys, under anaerobic conditions. While the mechanism of the reaction has not been definitely established, it is known to be related to depolarization by removal of hydrogen from the cathodic areas. It is suspected that sulfate-reducing bacteria utilize hydrogen from the cathodic areas for metabolic processes.

Some autotrophic and heterotrophic sulfate-reducing bacteria isolated from marine sediments have been found to utilize hydrogen autotrophically. The enzyme, hydrogenase, is believed by many research workers to be involved. Other observers hold the opinion that another enzyme is involved.

Studies on cathodic protection using mild-steel specimens have shown that much lower potentials suffice in the absence of *D. desulfuricans*.

Possible Lines of Attack: Preliminary investigations would be required to develop a simple assay method to determine the physiological activity of any bacterial species, selection of a suitable electrode system, and the influence of different media under varying conditions of temperature and pressure. Finally, the mechanism of hydrogen utilization from electrode surfaces should be investigated in cell-free extracts and purified enzyme preparations employing classical methods of enzyme chemistry.

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428. Decontamination Efficiency of Water Treatment Plants for Various Radioisotopes

The Problem: In cases of emergency, sanitary engineers and public-health personnel will need to know the reduction in radioactivity levels afforded by existing water-treatment facilities, and also what reduction is possible with a modification of procedures.

Increased industrial use of radioisotopes, development of atomic power plants, hazards related to transportation of atomic wastes, and the possibility of resumed testing of nuclear weapons all compound the problem of keeping radiological levels in our environment below the recommended safe levels. By establishing operating characteristics of conventional treatment methods for removing radioisotopes from water, the most efficient mode of treatment can be selected when needed.

Background Information: A considerable literature exists on the removal of specific radioactive contaminants by the unit operations used in conventional water treatment. In addition several reports have been made on the removal of natural fall-out by treatment plants. However, the latter have all been concerned with levels of radioactivity far below acceptable levels in the raw water.

Possible Lines of Attack: The physical and chemical properties of water are known to affect coagulation, and they can also be assumed to affect the removal of radioisotopes from water.

The new synthetic coagulant aids are known to affect the physical character of chemical flocs. Their effect on the adsorptive power of chemical floc for radioisotopes of various types should be investigated.

Attention should be given to removal of the common isotopes used extensively in industry, as well as fission products from nuclear detonation or nuclear reactor accident.

References:

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2. Bell, C.G., Thomas, H.A., and Rosenthal, B.L., "Passage of Nuclear Detonation Debris Through Water Treatment Plants", Jour. Am. Water. Works Ass'n., **46**, 973 (1954).
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429. Improvement of Membrane Filter Method of Evaluating Numbers of Coliform Organisms

The Problem: The membrane-filter method of evaluating numbers of coliform organisms has many advantages in its favor, particularly speed. However, its range of application is rather limited. There is considerable variation in the physical and bacterial quality of raw-water supplies and the membrane-filter method appears to be a less sensitive method of measuring the sanitary quality of water as the ratio of coliform to other organisms decreases.

In the analysis of potable waters, suspended matter and algae native to the water or picked up in distribution systems often complicate the enumeration of colonies on membrane filters.

Background Information: The membrane-filter technique of evaluating numbers of coliform organisms has had a relatively short history, having been developed in Germany during World War II and first brought to the attention of the American water-works profession by publications in 1951. Since that time numerous investigations have been conducted to determine its efficacy and many proposals made to overcome its limitations. The method was included as a tentative procedure for enumerating coliforms in the 10th edition of "Standard Methods for the Examination of Water, Sewage and Industrial Wastes" and advanced to an alternative standard procedure by action of the Executive Committee of the AWWA Board of Directors in November 1957. The elevation of the membrane method to a standard procedure makes it mandatory that studies be conducted to overcome known limitations of the test.

Possible Lines of Attack: Studies should embrace both standard procedures for routine and special analysis of raw and potable water supplies. Efforts should be directed toward the possibility of combining all or portions of presently known analytical methods with the membrane-filter technique. Modifications of these procedures and newly devised ones could be studied. Testing new or appropriate modifications of old culture media would be a worthy area of investigation.

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430. Effects of Controlled Recreation on Terminal Reservoirs

The Problem: A few agencies permit a limited amount of recreation, such as fishing and hunting, on terminal reservoirs. Sanitary facilities are normally provided and the recreationists are warned to avoid contamination of the water. A practical problem exists regarding the effect on water quality from such limited use and the possibility of some accidental or careless misuse of facilities. The problem is particularly significant for water supplies that receive only chlorination before admission to the distribution system.

Background Information: In many sections of the country where lakes and streams are abundant, the use of reservoirs for recreational purposes has been prohibited, particularly terminal reservoirs. In other areas where recreational waters are less abundant or where populations are large, there has been a growing pressure to gain access to water reservoirs. There has been considerable reluctance to permit such use in many areas, even when the water is subjected to full chemical treatment and filtration before use. In view of the polluted river waters that serve as adequate water supplies for many of our metropolitan areas after proper treatment, there seems to be little reason, except precedent, to guard and preserve the purity of a water supply so closely that is to be given the full treatment, anyway.

As populations increase, the pressure to use all waters for recreational purposes will increase. It seems important that studies be made on this facet of water supply so that realistic appraisals and decisions can be made.

Possible Lines of Attack: It will be necessary to work in close liaison with water works officials in any investigation of the type proposed. A plan of operation should be worked out and rigidly followed. An ideal way would be to operate on an alternate monthly basis with the numbers of people and their activities controlled according to plan. All forms of recreation should be studied, including swimming and bathing, provided that proper bathhouse facilities can be established. The problems peculiar to children should be explored. Complete sanitary chemical and bacteriological surveys should be conducted.

References:

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431. Screening of Potential Water Works Chemicals for Toxicity, Taste and Odors, or Other Aesthetic Aspects

The Problem: The chemical industry today is producing many new substances that might be applicable to problems in the water-supply industry. No standard procedure exists at present to serve as a basis for approving and determining acceptable limits for applications of new materials in the production of potable water supplies.

There is a need for more effective, economical solutions to many water-supply problems, and the use of newly developed chemicals might be an effective method if such materials could be approved within a reasonable time. Federal agencies are overburdened with routine testing. There is need for help at the grass-roots level.

Background Information: In the past twenty years, the chemical industry has produced a large number of insecticides, weedicides, coagulant aids, and similar chemicals. The application of these materials to potable water-supply problems is restricted owing to possible toxic or adverse aesthetic conditions. Although distributors often give verbal assurance of low toxicity levels, the producer usually labels these products advising against possible pollution of potable waters.

Relaxation of Federal directives forbidding the use of any material having toxic or carcinogenic properties in foodstuffs or allied substances to a more enlightened basis of acceptable levels, indicates that potable waters should be considered in the same manner, and suggests the reasonableness of permissible levels.

Possible Lines of Attack: A study should be made to determine to what extent various technical organizations, agencies, and industries are concerned with the problem and to coordinate ideas on the subject. A proposal for approving chemicals for use in potable water supplies should be developed to include the following factors: (a) A material subjected to test should bear evidence supplied by the manufacturer regarding the toxic levels and a guarantee by the manufacturer that materials supplied under other than exact chemical names will have a uniform composition. (b) A standard set of biological tests of scope and intensity designed to test the safety with respect to humans and animals. (c) A set of tests designed to determine adverse water-quality effects. (d) Finally, submission to an acceptable laboratory at the Federal level for rechecking and final approval.

References:

1. Anon, "Safety of Certain Coagulant Aids for Potable Water Treatment, Jour. Am. Water Works Ass'n., **50**, 462 (1958).

432. The Solubility of Magnesium Hydroxide

The Problem: What amounts of magnesium hydroxide will precipitate from aqueous solution at different temperatures up to boiling, and what factors, including presence of silicate and aluminate, influence its solubility?

Objective: To determine the solubility-product constant of $Mg(OH)_2$ over a temperature range of 0°-100°C, and to determine the effect of ionic strength on this constant. This study should then be extended to determine the influence of silicate ion and aluminate ion on the solubility product.

Background: As is well known, hard water contains salts of calcium and magnesium that under some conditions may lead to troublesome precipitates. Municipal softening of hard water is designed to prevent or minimize this problem. Magnesium hydroxide deposits resulting from improper lime-soda water softening may take place in hot-water tanks, hot-water lines, and distribution systems. In the first case, heat transfer may become so inefficient that cleaning may be required within a matter of a few weeks. In the second case, the deposition may become so great that the service lines in hospitals, institutions, and hotels fail to deliver water at remote points because of excessive head loss in transmission. In the third case, the deposit, although thin, is rippled and results in losses in carrying capacity of distribution systems owing to excessive friction loss. This problem is still giving costly trouble in communities where the lime-soda method is used for softening. The "improper" softening of the water in these situations is in most cases not from want of attention, but from current lack of scientific knowledge that the suggested research would be designed to supply.

Previous Work: Values of the solubility product constant reported in the literature vary from a pK of 10.5 to 11.6, and only one investigator has determined the solubility for more than two temperatures. None have considered the influence of silicate ion or aluminate ion. It is believed by some that the reaction with each is stoichiometric, but the evidence of one lone investigator seems to show the reaction to be one of adsorption on the magnesium hydroxide.

Potential Avenues of Approach: Standard solutions of magnesium salts with and without other additives may be titrated with standard sodium hydroxide under constant temperature conditions in a CO_2-free atmosphere, with recording made of pH (using a hydrogen electrode) and conductivity at suitable intervals. Care must be exercised to prevent solution of silica from glass contacts and to insure equilibrium conditions at the time of recording.

The work could take up to two years, depending upon the experience and qualifications of the personnel.

Requirements: A well-equipped and staffed chemistry laboratory should be able to conduct this research. The disciplines involved are inorganic or physical or analytical chemistry, at either the predoctoral (graduate) or postdoctoral level. The research should serve as an excellent subject for a university graduate-school thesis.

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433. Tertiary Treatment of Waste Waters

The Problem: Municipal sewage is conventionally given "primary" treatment to remove the coarse components and settleable solids when dilution of the effluent is adequate, or "secondary" treatment by biological means to remove colloidal solids and dissolved organic matter when the effluent is discharged to limited watercourses or perhaps to ground-water recharging basins. With increasing demands upon our water resources, however, and with concomitant growth of population and industry, many situations are arising where known methods of secondary treatment are not adequate. Even well-oxidized effluents may contain excessive concentrations of nitrates and phosphates, or trace elements such as boron, that render subsequent reutilization of the water hazardous for human consumption and other beneficial uses. For waste-water reclamation and reutilization, "tertiary" treatment appears to be necessary.

The Nature of Tertiary Treatment: The effluent from conventional secondary treatment plants can be polished by coarse-grained and fine-grained filters of the rapid or slow type to the extent that all suspended matter and turbidity are removed and the final product is sparkling clear. Yet, it will still contain dissolved minerals and some organic substances acquired from domestic or industrial use, such as polyphosphates and alky aryl sulfonates from detergent compounds, and it will have an increased concentration of nitrates, borates, bicarbonates, sodium, and other solids. These substances cannot be removed by conventional secondary processes or by polishing filtration. They will require entirely new approaches, the nature of which will involve considerable research.

Potential Research: One project might explore methods by which quarternary compounds and especially alkyl benzene sulfonate can be attacked biologically. Certainly there must be a bacterium, fungus, or creature somewhere that can decompose these formidable organic substances. To find it and cultivate it under ideal conditions is a significant research project. Perhaps a synergistic combination of organisms is needed.

A second project might investigate reactions for precipitating borates, or perhaps removing them by adsorption or ion exchange. Perhaps they are subject to biological adsorption and synthesis, if only the right organism can be found. Nitrates and phosphates, for example, can be synthesized biologically, but perhaps methods more efficient than algae ponds should be explored.

Selective ion-permeable membranes have been used in several processes for de-ionization of brackish waters. Perhaps these membranes, or modifications of them, can be made to remove nitrates, phosphates, and/or borates without other anions. Here, we should call upon plant physiologists for assistance to learn how the roots of plants are able to select nitrates and phosphates while rejecting chlorides and sulfates. A thorough study of the selective action of plants toward dissolved minerals is a third project that might unlock the door to economical tertiary treatment

As a fourth project, further exploration of chelation as a mechanism for selective removal of certain cations might be undertaken.

It may be possible to obtain an efficient exchange of cations by passage of the sewage effluent through a bed of an inexpensive chelating agent. Perhaps certain lignins, a waste product of the pulp industry, would serve in this capacity. In any event, much research can be done to investigate chelation as a method of tertiary treatment.

SECTION V. SOLID WASTE DISPOSAL AND MISCELLANEOUS PROBLEMS

Problem No.	Title
501	What Effect Does the Burial of Refuse Have on the Quality of Ground Water?
502	What is the Value of Refuse Compost in Agriculture and Horticulture
503	Compression, Baling, and Sealing of Refuse
504	Disposal of Combustible Trash to Sewers
505	Control of Harmful Flying Insects
506	Isolation, Identification, and Control of the Principal Types of Algae in Swimming Pools

501. What Effect Does the Burial of Refuse Have on the Quality of Ground Water?

The Problem: A major method of refuse disposal is burial in sanitary landfill. Often this burial can be done in areas where there is no possibility that usable ground waters could be effected by any gases or leaching from disposal sites. Refuse could be buried or is being buried at many sites where the possible effect on ground water is of concern. Categorical forbidding of all such operations would be a "solution" of the problem. However, there are many areas where there is a large economic advantage in using sites overlying ground-water basins insofar as this can be done safely. Research on this subject will provide information as to the effects of refuse on ground water, so that adequate safeguards can be established in such operations, while at the same time allowing maximum use of such disposal sites.

Past Efforts: Research projects sponsored by the California State Water Pollution Control Board, and conducted by Prof. Robert Merz of the University of Southern California, have provided information on changes of ground-water quality in the vicinity of a dump along the Santa Ana River, where ground water moves through the dump. Studies have also been made by Prof. Merz, on a laboratory scale, of the quality of water leaching through ash from an incinerator, and an attempt was made to secure observations on existing ash dumps. A theoretical study was presented in a report on refuse disposal by Los Angeles County Sanitation Districts. In this report, attention was called to the fact that carbon dioxide from a dump might affect water which does not itself come in contact with the refuse. Observations have been made of the composition of gas in deposits of organic refuse both in New York City and in Long Beach, California.

Avenues of Approach: Studies similar to those made by Prof. Merz may be made at other dump sites where water is in contact with refuse, leading to more generalized conclusions than are now possible. Observations may be made of the carbon-dioxide content of the soil gas near refuse deposits, its rate of diffusion through the soil, and its rate of diffusion into moving ground water. All other possible contaminants may be considered with attention to the amounts which can reach the ground water, possible travel through the soil, and possible concentrations in ground water supplies.

Other Considerations: This problem is acute in southern California, and the research probably should be done there. However, it may also be acute in other places not known to the writer.

Research on this subject has been advocated by many people in regulatory organizations, such as the Executive Officer of the Regional Water Pollution Control Board of the Los Angeles region. The Board must make decisions in respect to refuse disposal practices, and would be greatly aided by more information.

The California State Water Pollution Control Board is currently sponsoring a project to collate and evaluate all available information on this subject. The report of this project will indicate many potential programs for research.

502. What is the Value of Refuse Compost in Agriculture and Horticulture?

The Problem: Many communities have been interested in composting of refuse as a means of its disposal but they have rejected the method because of economic considerations. A few cities in the United States have permitted private concerns to establish refuse composting plants but such concerns usually base their operations on profit from the compost sales, charge exorbitant prices, and fail in a relatively short time owing to financial or other difficulties. The time value of compost has not been established either by the method of supply and demand in an area with continuous production over a number of years or by agronomic research to determine its value when applied to various types of soil and the yield increases caused thereby for various crops. Refuse composting as a competitive sanitary method of disposal of community solid wastes can never become established if, on the one hand, the demand and sale price of the end product must be known in *advance* and, on the other hand, its demand and sale price can only be established *after* compost has been produced in volume over a lengthy period.

Previous Work: Refuse compost production and sale have been established for many years abroad, particularly in Europe where more than 50 plants are in operation, including 15 in the Netherlands handling over 25% of all municipal refuse in the country. Moreover foreign countries, notably the Netherlands and Germany, have conducted extensive agronomic research on the value of the locally produced compost in agriculture, horticulture, viviculture, and silviculture. Two leading organizations are Stichting "Compost" (the Compost Foundation) in Amsterdam and the Institute fur Humuswirtschaft, Bodenfruchtbarkeit and Pflanzernahrung, Forschungsanstalt fur Laudwirtschaft, Braunschweig--Volkenrode, Germany.

The European consensus is that refuse compost is a soil builder or soil amendment, not a fertilizer; that it replenishes the organic matter or humus of the soil; and that fertilizer and compost are complimentary--both being applied as needed for the greatest yields. Chemical and physical soil fertility are distinguished, the latter being as important as the former and comprising such properties as friability, aggregation, moisture and air holding capacity, and absorbability for soluble chemical nutrients. Compost, in addition to improving soil structure, making plowing easier, permitting greater water retention to carry over during drouths and to prevent erosion by wind and rain, and increasing soil organic matter and microorganism activity, also provides a limited amount of major plant nutrients (N, P, K, C) and probably adequate amounts of most trace minerals needed by plants. These benefits render useless the determination of the value of the compost on the basis of N, P, and K contents as is done with chemical fertilizers.

No similar studies have been made in the United States, While some of the findings may be extrapolated to U.S. conditions, both U.S. refuse and U.S. soils may be considerably different. For example, European refuse contains much more ashes, and much less metals, glass, and paper than U.S. refuse.

Possible Lines of Approach: Being unable to resolve the problem on a basis of price establishment by supply and demand, a more productive method of approach appears to be by agronomic research and the computation of value of compost by the increased yield produced through its application to the soil. Europeans have established a regime of relatively large applications of compost at two- or three-year intervals. Findings indicate a delayed benefit of compost application, sometimes none or negative for the first season but increasing in the second and third seasons and in some cases showing effects for 10 or more years after application. Although pot trials have some value, European experience has indicated more benefit is obtained with plot or field studies. Such studies should not pit chemical fertilizers against compost because the two do not have similar functions; but they should probably include for each soil and crop used controls with no treatment and with chemical fertilizer treatment and tests with the latter plus various application rates of compost. Because of the long-term benefits of compost the studies may be of sufficient duration but some valuable results might be expected by about the third year of study.

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503. Compression, Baling, and Sealing of Refuse

The Problem: Refuse in sanitary land fills undergoes biochemical decomposition with resulting gas production and settlement. The gas may create an odor nuisance, an explosion hazard, or a degradation of nearby ground water. The settlement may interfere with subsequent use of the land for construction or even for recreation. If ground water rises into or passes through the sanitary land fill, such water may become grossly polluted and unfit for subsequent use.

Potential Solution: It should be possible, and perhaps economically feasible, to compress and bale municipal refuse in a manner similar to cotton. The bales could then be placed in a sanitary land fill in an orderly space-saving manner, and they should be free from subsequent consolidation. Indeed, owing to their density, they should be less subject to biochemical action than loose refuse. If the bales could be coated with paraffin, plastic, bitumastic, or other waterproof material, they should be able to withstand the intrusion of ground water. Perhaps, the bales should be so placed in the sanitary land fill that they are interspersed with volumes filled with soil or even with air. Compression, baling, and coating might be performed on the collection vehicle, but more likely at a central collecting and transfer station.

Possible Lines of Attack: This problem is so unique that an empirical trial-and-error approach appears to be the only method of attack. What commercial baling equipment is available and can it be adapted to refuse? What pressures are optimum for the compression? Will the bales consolidate further in a land fill or will they expand and break their bonding wire? At what rate will they undergo biochemical degradation? What is an optimum moisture content for compression and also for minimum decomposition? Should bales without a sealing coat be placed in contact with each other or should they be separated by soil or air?

There is a possibility that coastal communities might dispose of sealed bales of refuse in deep ocean waters. Normal refuse has a large component of flotable material that will wash back on shore, but dense bales should sink and stay there. What is the action of sea water on compressed bales without sealing? With various sealing compounds?

Most important are the economic factors. What are the estimated costs of baling and sealing? Do the benefits justify the costs?

504. Disposal of Combustible Trash to Sewers

The Problem: For many communities, the annual per capita cost of handling and disposing of refuse is five times or more the cost of operating and maintaining the sewer system. A large proportion of the refuse cost, perhaps 90% or more, is attributable to collection and transportation whereas for sewage these chores are accomplished by the water-carriage system of waste conveyance. Would it be possible, advantageous, and economically feasible to use sewers for the dual purpose of carrying shredded refuse as well as sewage? How can this concept best be accomplished?

Background: Patterns of refuse collection, transport, and disposal vary markedly among American communities. In some instances, combustibles, non-combustibles and/or garbage are segregated by the householder for separate collection. The trouble of segregation and the costs of separate collection are supposedly justified by the salvage values of cans and bottles, and the feeding of garbage to hogs. Careful analysis of the true costs, however, generally shows that the taxpayers are subsidizing the reclamation operations, and that combined collection of all solid wastes is much less costly on an overall basis.

In recent years there has been a strong trend toward the installation of household grinders for the disposal of garbage to the sewers. Many new communities, in fact, have complete installation of such equipment and hence no need for garbage collection. In others, all new residences must be so equipped.

While it is not logical to expect each householder to install a king-size grinder to shred his combustible refuse such as cartons, paper, and tree trimmings, there is a distinct possibility that the costs of municipal refuse collection, transportation, and disposal could be reduced substantially by the construction of neighborhood refuse-grinding stations that discharge to trunk sewers. In this manner, the long costly hauls to disposal sites and the present costs of disposal would be eliminated. Perhaps the collecting vehicles could be equipped with grinding devices and discharge directly through manholes to the sewers.

Collection and grinding would entail the separation of combustibles from non-combustibles, either by the householder or by a sorting process just prior to the grinder.

Possible Lines of Attack: This problem is one that involves development and economic analysis rather than basic scientific research. It is necessary to evaluate the existing and potential designs of grinding equipment, both stationary and mounted on collection vehicles. Methods for the mechanical sorting of non-combustibles from refuse need improvement. An economic analysis might well be made of the proper spacing of fixed grinding stations and the feasibility of sorting and grinding on the collection vehicle.

An important aspect is the effect of shredded trash on municipal sewers and sewage-treatment plants. Will the added cost of disposal at the treatment plant be less than separate refuse disposal at a land fill or incinerator? What will be the effect on sludge digestion and disposal? Will there be an economic value to the additional gas production? These questions and many corollary ones deserve thorough engineering economic analysis.

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505. Control of Harmful Flying Insects

The Problem: Insects are major factors in our public welfare and health. Among the many types that plague our everyday life are included species of the housefly *(Musca)*, the vinegar or fruitfly *(Drosophila)*, the oriental fruit fly *(Dacus)*, and a variety of other flies and insects in the *Diptera.*

Background Information: In recent years the development of chemical insecticides has contributed greatly to the control of such insects. However, these insects are gradually developing an immunity to the new chemicals. Furthermore, the fact that they tend to distribute themselves over very large areas makes these pests particularly difficult to treat.

These facts suggest that a satisfactory form of control might result from the use of a substance which would attract specifically undesirable species from a broad area to a central location where treatment with insecticides could be made most efficiently.

Possible Lines of Attack: One approach to such a problem would involve chemical investigations of insects' mating attractants and perhaps others. There is ample evidence to indicate the feasibility of such an approach.

The studies, of course, would involve the isolation and identification of sex attractants in insects. The applied aspects of such studies are apparent.

Special Requirements: These studies would necessitate the use of a laboratory equipped for entomological work for organic chemistry

Special Requirements: These studies would necessitate the use of a laboratory equipped for entomological work, for organic chemistry and the necessary physical instrumentation.

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506. Isolation, Identification, and Control of the Principal Types of Algae in Swimming Pools

The Problem: A major factor in the sanitary maintenance of outdoor swimming pools is the suppression of algal growths, especially attached algae. Before effective methods of control can be devised, it would be well to know more about the taxonomy and morphology of these plants.

Background: The number of outdoor swimming pools, especially in the South and Southwest, is increasing phenomenally. Many of these pools serve motels and apartments; hence they are semi-public and come under the inspection and supervision of local health departments. Pool owners rely upon advice from the health departments, but they are also dependent upon equipment and supply firms that sell chemicals and maintenance service. Often the advice from these groups is not consistent, especially if proprietary products are being promoted. Among areas of uncertainty, the control of algae is subject to the most speculation and ignorance.

While plankton are sometimes troublesome, the attached algae represent the major problem. The free-floating organisms are removed by the conventional recirculation processes involving filtration through sand or diatomite. Attached algae are immune from this procedure. They generally grow on the submerged walls and bottom of the pool and they are remarkably resistant to many algicides.

Sometimes they have to be removed by a wire brush. The species may vary from season to season and perhaps there are geographical differences.

Possible Lines of Attack: The initial phases of this project will probably involve a survey of numerous pools to collect and identify the principal types of algae, especially the attached forms. This survey should continue for at least a year and preferably longer. It should cover as wide a geographical area as possible, or perhaps a cooperative effort could be developed among several groups in different parts of the country.

At the time of collection of algae, information should also be gathered about the operation of the pool, the bathing load, chemical treatment being used, and the chemical quality of the water. Such data may turn out to be important in relation to the occurrence and resistance of the organisms.

Simultaneously with the taxonomical studies, it should be possible to conduct laboratory experiments to determine the response of the predominant algae to factors such as pH, chlorine residual, nitrogen compounds, alkalinity, and various algicides.

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